ESTONIAN UNIVERSITY OF LIFE SCIENCES
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TRACKING THE CHANGES OF URBAN GREEN AREAS IN THE CITY OF BAGHDAD FOR THE PERIOD OF 2000-2018

Master's thesis
Curriculum in Landscape architecture

Supervisor lecturer
Prof. Simon Bell, PhD

Tartu, 2019

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Abstract

During the past 18 years, Baghdad (the capital of Iraq) has been experiencing many radical changes in its political, economic, and cultural fronts. Whether through the invasion of 2003 or what followed after of proxy wars or terrorist attacks. All of this mischief has put to the government focus on security issues facing the country, and the rebuilding of infrastructure projects, which has led to destruction and neglect of a large amount of the city's green infrastructure among other things through illegal building on private gardens and agriculture designated areas. This, in turn, has resulted in large sealed surface increasing and high urban heat island effect, which is being felt and reported by the city's residents. In order to have some background, this thesis looks at first at the development of the master plan of Baghdad and the current governing bodies that control and regulate green areas, in addition to exploring literature to understand the benefits of green areas and trees for shade, thermal comfort, and improving the air quality. Then through the two methods: tracking the changes that have occurred in Baghdad in regards to the amount of green areas and number of trees through the mapping of four representative areas of different economic levels and time period building and historical value, and through questionnaires spread through social media, surveying the people's perception of the city and their understanding and priorities when it comes to green areas and trees. It concluded that there has been a large loss in private gardens areas in all of the study sites neighbourhoods, and the disappearance of the agricultural outskirts of the city, which is referred to as "the green belt". Moreover, that the people's perception of these changes has been verified by mapping results of Baghdad.

Keywords: Baghdad, thermal comfort, life quality, air quality, green areas quality, recent history of Baghdad, urban tracking, urban green tracking, heat island effect, shading trees, post-war environment, desert cities, history of Baghdad's master plan development, private gardens tracking.

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Abstract

Viimase 18 aasta jooksul on Bagdad (Iraagi pealinn) kogenud mitmeid radikaalseid muutusi nii poliitika, majanduse kui kultuuri vallas, seda kas 2003. aasta sissetungi või sellele järgnenud varisõdade ja terrorirünnakute tõttu. Kõik see on pannud riigi valitsuse keskenduma julgeolekuküsimustele ja infrastruktuuri taastamisele, mis omakorda on põhjustanud suure osa linna rohealade hävitamise või hooletusse jätmise, mis muuhulgas hõlmab ebaseaduslikku ehitustööd eravalduses olevates aedades ja põllumajanduslikul maal. See omakorda on kaasa toonud suletud pindade osakaalu ja linna soojussaare efekti suurenemise, mida linnaelanikud tajuvad ja raporteerivad. Eesmärgiga anda taustaülevaade, käsitleb käesolev uurimus Bagdadi üldplaneeringu arengut ja praeguste võimuorganite tegevust, kes kontrollivad ja reguleerivad rohealasid, lisaks käsitletakse kirjandust, loomaks arusaama rohealade ja varju pakkuvate puude kasulikkusest, soojusmugavusest ning õhu kvaliteedi parandamisest. Seda on tehtud kahel meetodil: jälgides Bagdadis toimunud muutusi rohealade ja puude hulga osas, kaardistades selleks nelja representatiivset ala, mis erinevad omavahel elatustaseme, ehitusperioodi ja ajaloolise väärtuse poolest, ning levitades sotsiaalmeedias küsimustikke, saamaks aimu, kuidas inimesed oma linna tajuvad, ning millised on nende arusaamad ja prioriteedid rohealade ja puude osas. Kokkuvõtteks saab öelda, et kõigis uuritud piirkondades on toimunud isiklike aedade hulga laiaulatuslik vähenemine, samuti põllumajandusliku maa, millele viidatakse ka kui haljasvööndile, kadumine linna ümbrusest. Ka inimeste teadlikkus nende muutuste toimumisest on Bagdadi tulemuste kaardistamisel kinnitust saanud.

Keywords: Bagdad, soojusmugavus, elukvaliteet, õhukvaliteet, rohealade kvaliteet, Bagdadi lähiajalugu, linna struktuurimuutuste vaatlemine, linna rohealade struktuurimuutuste vaatlemine, soojussaare efekt, varju andvad puud, sõjajärgne keskkond, kõrbelinnad, Bagdadi üldplaneeringu arengu ajalugu, eraaedade struktuurimuutuste vaatlemine.

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TERMINOLOGY

Term	Meaning
Functional trees	Trees that are planted for their thermal energy mitigation, in addition to pollutants cleaning from the air, soil, and water.
Ornamental trees	Trees and plants that are mainly planted for their aesthetical value and symbolic importance.
Fruit trees	Trees that are planted for their fruits.
Green areas	Can include everything that is vegetation related (agriculture, gardens, parks, forests, trees, green roofs, etc.).
Green structures	can include manmade vegetated areas (parks, gardens, agricultural areas
The green belt	the green areas that used to surround Baghdad implemented by planners from the 1950s-1970s
At home (in relation to the questionnaire)	The private gardens that people have (or would have) at their homes.
Outside the home (in relation to the questionnaire)	Anything that is outside the ownership of the private home, from side-walks to areas next to highways to public squares and spaces.. etc.
Rusafa	The east bank of the Tigris River.
Karkh	The west bank of the Tigris River.
MCHPM	Ministry of Construction and Housing and Public Municipalities
Open areas (from mapping)	Areas that are not green, not streets or built. These areas (that are not developed) could have a land cover of desert looking (sand for example). An example of this could be a main square that has built streets around it, however, its cover is not asphalt nor green.
Empty lots (from mapping)	Areas that are designated to be built on in the future.
Built areas	Areas that are manmade and are not green (Buildings, streets, sidewalk).

CHAPTER ONE: INTRODUCTION

1.1 Introduction

For the past 15 years, there has been great neglect when it comes to the green structures in the city of Baghdad. Throughout this neglect, the city have been suffering higher urban island heat effect. This neglect, whether political or circumstantial, had had a great effect on the functions and works of the government in regards to green areas, and had pushed green structures out of the picture when it comes to the priorities of people, and governmental planning and oversight.

1.2 Some background about what have happened in the city of Baghdad in recent history

After the 1980-1988 war between Iraq and Iran, Iraq had very limited time to recover from this long war when in 1991 an embargo with international sanctions (UNSC, 1991) were put on Iraq's economy and that lead to the country being in isolated state. Until the 2003 invasion of Iraq and the ousting of the Saddam Hussein and the Baathist ruling party which was led by the United States, which put the country in a state of chaos. The country faced years of unrest, civil war, and being a battleground for terrorist groups. This of course led to a huge amount of destruction in the infrastructure of the country in general, and the city of Baghdad (the capital of Iraq) in particular. That forced high internal migration in Iraq to Baghdad for economic, safety, and security reasons. All of these events have created a state of unsettling politics and military conflicts that were the focus of the governments that ruled after 2003. In addition, resulted among other things such as internal migration, to the neglect of green urban structures, rural and agricultural areas. Along with the lack of regulation and the lack of implementing said regulations, that lea to the loss of large amount in private gardens that were transformed into built structures.

1.3 What is the problem in general

The current heat situation in the city of Baghdad is getting more extreme by the year because of the continued urban 'heat storing' spreading of building and the eradication of green areas and the decrease of home (private) gardens. Which has led to the

increased dependence on air conditioning devices to control and improve the temperatures indoors, which has led to creating a city that is polluted with the heat of these devices, in addition to the heat storing by the mass of buildings, streets, and sidewalks which all of those emit the heat back to the city atmosphere during the night-time (Al-Jawadi et al., 2014), and since the demand for more housing is growing because of the increasing internal migration from the rural areas of Iraq, that is creating a more population dense city. (Jones, 1969), (Burnham et al., 2006). Which in turn means more built sealed surface and less green areas.

1.4 Thesis organisation

This thesis was organised into six chapters, **chapter One** being an *introduction* to the thesis and a brief history of what had happened in Baghdad recently and explaining what is the current problem , along with the hypothesis, and research objectives. **Chapter Two** looks into the *development history* of the master plan of *Baghdad* in addition to looking into the current *governing bodies* that control and regulate green areas through interviews conducted with government officials. **Chapter Three** explores *literature* to understand the benefits of green areas and trees for shade, thermal comfort, and improving the air quality, in addition to research related to studies conducted in Baghdad about its climate. **Chapter Four** describes and strategies the two *methods* used: 1) to choose the sites, the time period, and the analysing of these sites in regards to changes in green and sealed surfaces during the specified time period. 2) The questionnaire development, administration and analysis. **Chapter Five** shows the *results* that were found in regards to the two methods. **Chapter Six** is the final chapter that includes the *discussion* of the results, and the *conclusions* of the thesis. In addition to the *recommendations* for different levels of people, and the summary and final thoughts of the study. (Figure 1.1) shows the thesis structure and analytical development.

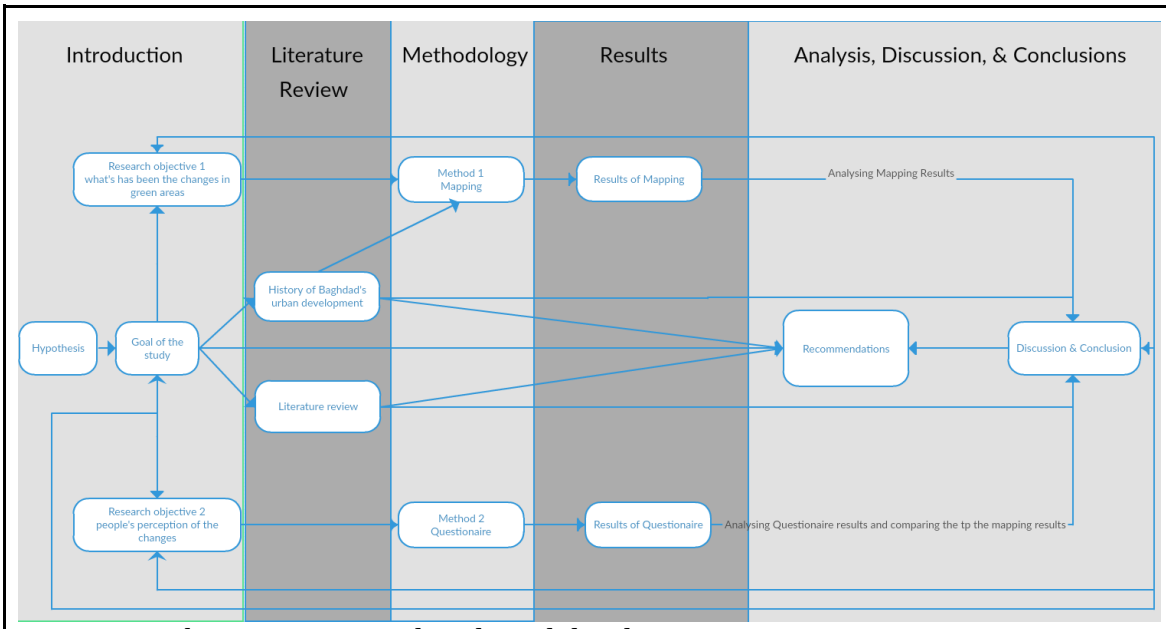


Figure 1.1 Thesis structure and analytical development.

1.5 My hypothesis

The quality in the urban environment is decreasing as a result of the loss of greenery on the one hand and the increasing in built structures on the other, which are both massively interconnected thus leading to a reduction in the quality of the living environment, thermal comfort, shade, and air quality.

1.6 The research objective

- To assess the changes that have occurred in the city of Baghdad in regards to the amount of green areas and sealed built surfaces.
- To understand the perception of people in Baghdad towards green structures and their priorities and understandings of the benefits of green areas.

These objectives were transformed into research-oriented questions that the thesis will attempt to answer at the end:

1. What have been the changes of green areas in the city of Baghdad in recent history (2000-2010)?
2. What is the perception of the people in Baghdad towards green structures and their priorities and understandings of the benefits of green areas?

The Goal of this study is to find solutions to create comfortable outdoor environments naturally, by the utilization of shading techniques to block the sunrays from buildings,

streets, and sidewalks by trees. Thus decreasing the sensible air temperature air throughout the daytime, in addition to the reflected and emitted heat by the urban surfaces, including the emitted temperature that is being stored by the mass of those urban structures throughout the night-time.

CHAPTER TWO: THE HISTORY OF URBAN DEVELOPMENT IN BAGHDAD

2.1 Introduction

This chapter will look in the history of urban development in Baghdad, through looking first at the history of Baghdad and the way it developed from the Abbasid dynasty creating it in the 8th century, until the Ottoman ruling and the 1920s overturning of them by the British mandate. After that, this chapter look into the different urban plans that were made for the city and their effect on its development until the 1990s. Finally, it will look into the current government bodies in charge of the development of Baghdad and the way this government bodies function and the issues that they are facing.

2.2.1 The creation of Baghdad

In 763, Abu Ja'far Al-Mansour founded the city of Baghdad to, to replace Damascus as the capital of the Abbasid dynasty. Positioned strategically in the heart of Mesopotamia, on the Tigris River, roughly, 500 km north of the Persian/Arabian gulf. After its creation, during the next five decades, Baghdad would become the most important capital of the Arabic civilization, and an intellectual centre for the Islamic world (Figure 2.1), and one of the most important cities in the world. It was a centre for science, education, and culture during these decades. The city was established to be on the two shores of the Tigris river, (Figure 2.2) showing with the circular city on the west bank of the Tigris, and later on, army and farming quarters outside the walls of the Round city and on the east bank of the Tigris river (Al Muhannak, 1997).

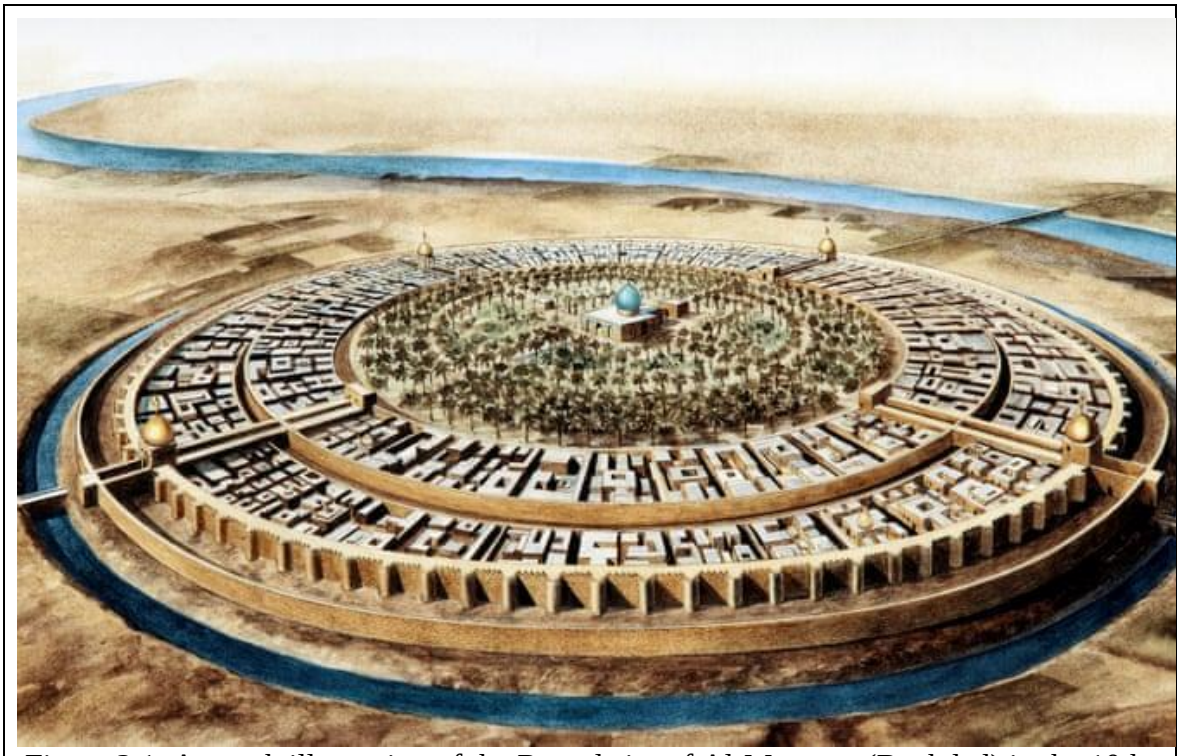


Figure 2.1. Artwork illustration of the Round city of Al-Mansour (Baghdad) in the 10th century, the peak of the Abbasid Caliphate. (Soutif)

During that time, Baghdad became a centre for commerce and trade, since it had a strategic location of being in the centre of Iraq, and by the Tigris River, which made it a perfect stop for traders (Al-Allaf, 1960). Coming "on the east-west trade route from Asia to the Mediterranean and the north-south pilgrimage route to Karbala, Najaf, and Mecca". (Levine, 2015).

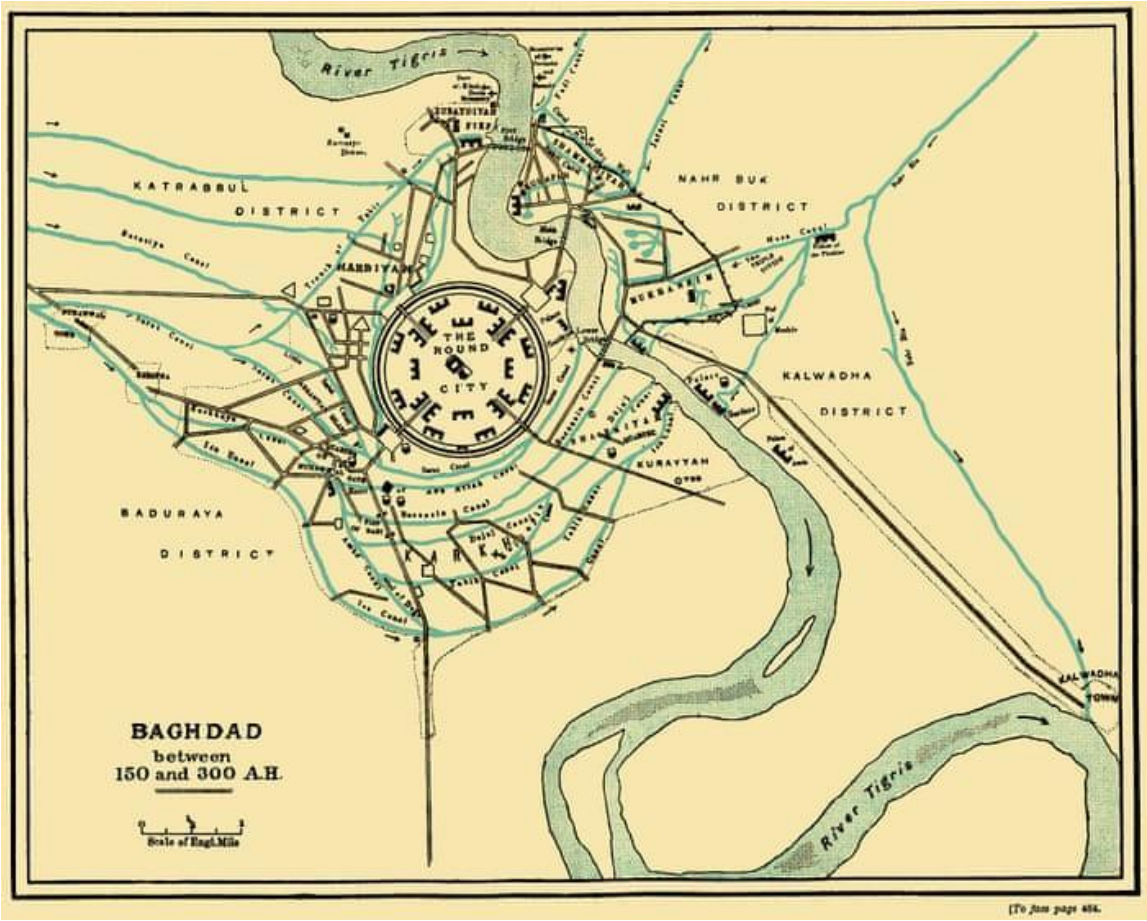


Figure 2.2 Round city of Al-Mansour (Baghdad), 762-766, site plan. (Le Strange, 1900)

2.2.2 The Mongol and Ottoman ruling of Baghdad

In 1258, the Mongols conquered Baghdad, but they did not care much about the sciences, education, and culture, in fact they seeked to destroy libraries and schools when they first occupied the city. Later Baghdad became a provincial capital under the Ottoman Empire. During that time, the city continued to function as a trading stop, the rulers of Baghdad cared only about collecting taxes, which led to a great ignorance, poverty, and the deteriorating economic situation and the people were suffering from oppression, tyranny and arbitrariness to the city and its dwellers. Until 1869 where Midhat Pasha started ruling Iraq. he started with a large-scale reform campaign of urban and cultural projects, such as paving main streets and markets, and creating a horse-drawn tramways to connect the city to it's remote parts which people at the time still used animals to reach or by walking, all together with a central post office, steamboats, and a printing shop and news papers (Al-Allaf, 1960).

in 1921 Baghdad became a capital again of the British mandate of Mesopotamia after the fall of the Ottoman empire, it later became the capital of the newly independent nation,

Kingdom of Iraq in 1932. (Hunt, 2005). Over the next 50 years, the city's population grew and Baghdad became a modern metropolis. (Jones, 1969), (Burnham et al., 2006).

2.3.1 The beginning and history of Baghdad urban development and urban development.

After the initial creation planning and the Abbasid dynasty, there wasn't much planning during the era of the Ottoman empire and after the Mongols conquered the city in general, just organic growth of the city until the 1860s and after with ruling of Midhat Pasha. Until the starting of the English ruling of Iraq in 1921.

When the British started ruling Iraq in the 1920s, they took some planning projects in Baghdad, for example erecting levees to prevent flooding, and creating new departments were created to control and create in some cases; postal services, telephone access, for these projects and for building new bridges, and the creation of a more comprehensive transportation networks, to connect Baghdad to the rest of the country and other countries through train, highways, and airplanes strips. Moreover, for the first time, the grid plan was introduced, and applied in Baghdad. (Harrington, 2014) (Levine, 2015).

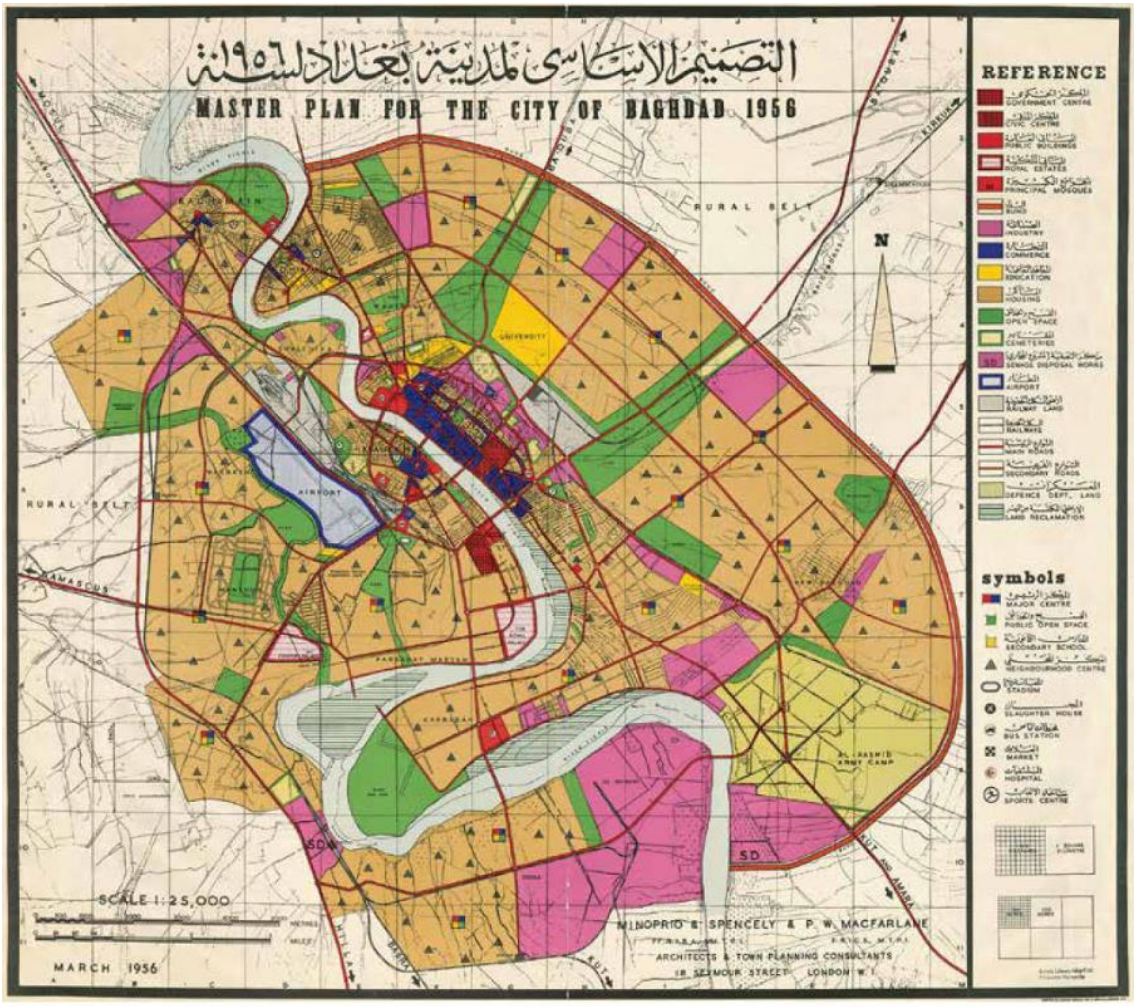
2.3.2 The "Iraq mandate", "Kingdom of Iraq" era

During the period from (1920-1932) and after which is also called the Iraq Mandate. almost all the projects were commissioned by British architects. After 1932 Iraq became the independent (Kingdom of Iraq) ruled by and renegotiated it's share of the oil profits from the IPC (Iraqi Petroleum Company) from the previous 25% to a 50% deal, which gave Iraq enormousness funds, to manage this money, a semi autonomous development board was created in 1950 by the government lead by Iraqi prime minister at the time Nuri Al-Sa'id (Harrington, 2014), and it received 70% of the annual income of oil revenues. Its goal was to create "a general economic and financial plan for the development of the resources of Iraq and the raising of the standard of living of [it's] people" (Levine, 2015).

2.3.2.1 Minoprio & Spencely, and P.W. Macfarlane plan

Some of the names that worked in Iraq was the town planning company, Minoprio & Spencely, and P.W. Macfarlane after their work in Kuwait and Crawley. They were hired in 1954 by the IDB (Iraqi Development Board) and the mayor of Baghdad to prepare study the old parts of the city, and to develop the master plan for Baghdad. They delivered their work in 1956; their work consisted of an approximately ninety centimetres squared

coloured plan (Figure 2.3) that was drawn over a surveyed map of Baghdad, along with a twenty-four pages of a Master Plan for the City of Baghdad. The plan depicts an extension to the city of around twenty kilometres on the north-south axis, and a fourteen and a half kilometres on the east-west axis, "with the entire ovoid-shaped city surrounded by a rural belt" (Levine, 2004).



10.14. Baghdad Master Plan, Minoprio, Spencely, and Macfarlane, 1954–56. Map and Geospatial Information Center, Peter B. Lewis Library, Princeton University

Figure 2.3 Minoprio, Spencely, and Macfarlane's proposal for Baghdad Master Plan 1956 (Levine, 2015).

The plan consisted of functional zoning in general, and the environmentalization of the city, varying housing units, but averaging of ten thousand inhabitants per neighbourhood. Each neighbourhood would have its own services centre, defined on the map as grey tringles which consists of shops, clinic, a masque, and other services. As well as a primary school and some open green areas such as fields and gardens. Defined as a red, blue, green, and yellow square on the map are the larger centres between

neighbourhoods. Which could include in addition to the smaller centres, a middle school that could serve multiple neighbourhoods. While keeping a rural belt around the city to maintain it from continues spread of development.

And to deal with the transport issues, they proposed new bridges to connect east and west banks of the Tigris, alongside new streets in the city while maintaining old streets in the downtown commerce centre and working as a connection to them (Levine, 2015).

2.3.2.2 Doxiadis Associates Plan

Another important planner was Constantinos Doxiadis, a Greek architect and town planner. His Greek background, imperialist stigma that distinguished him from the western consultants and technicians that were coming to Iraq during that time. Thus he was chosen by the Iraqi Development Board in 1956 to develop a master plan for Baghdad, spatially after the growing anti-western stigma that was growing with the people after the coup/revolution of Jamal Abdul Nasser in Egypt in 1952 (Khan, 2010).

Doxiadis concept allowed infinite theoretical expansion. He did set an ideal population limit of 3 million, three times the population of Baghdad when he was commissioned. His plan was "defined by an elongated rectangle oriented along the main northwest-southeast axis of the river." (Pyla, 2008).

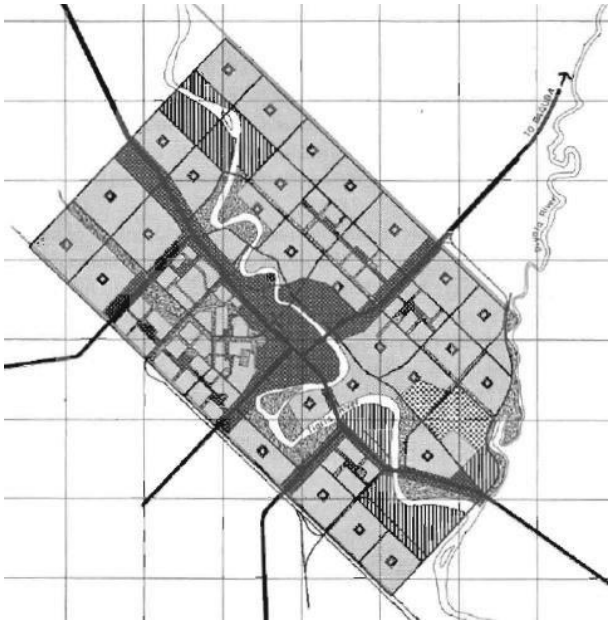


Figure 2.4 Doxiadis Associates' Master Plan for Baghdad, 1958. (Pyla, 2008).

Doxiadis design was influenced by the European and soviet examples, but not with the history of Baghdad. He proposed the demolition of a large area of the historical centre,

and according to (Harrington, 2014) “All parts of the plan were connected to the rectilinear pattern that had a commercial centre at its core, surrounded by 19 residential sectors with smaller neighbourhoods subdivided inside. A new road system provided easy access out of the city, to the country. Industrial districts were relegated to the edges of the city.” this plan separated the people by economic level, and created residential sectors. Contrary to what old neighbourhoods of Baghdad used to look like of having people from different economic levels living within the same neighbourhoods, with small twisting alleys of it’s souks that help give shade throughout the day, and having the houses open to the internal courtyard, he instead pushed to the front of the house with large windows, which meant much less privacy for the people who are relatively very conservative and losing the climatic benefits of cooling the house and privacy benefits of the internal courtyard. He as well introduced the use of concrete instead of local materials for building, and neglected materials like wood that were used for Shanasheel, that reduced light and heat, and gave privacy to the inhabitants of these houses. This reflect the lack of knowledge of local Architecture, culture, and history, and his assumption that designs from other places would be applicable in Baghdad without any adjustments (Pyla, 2008).

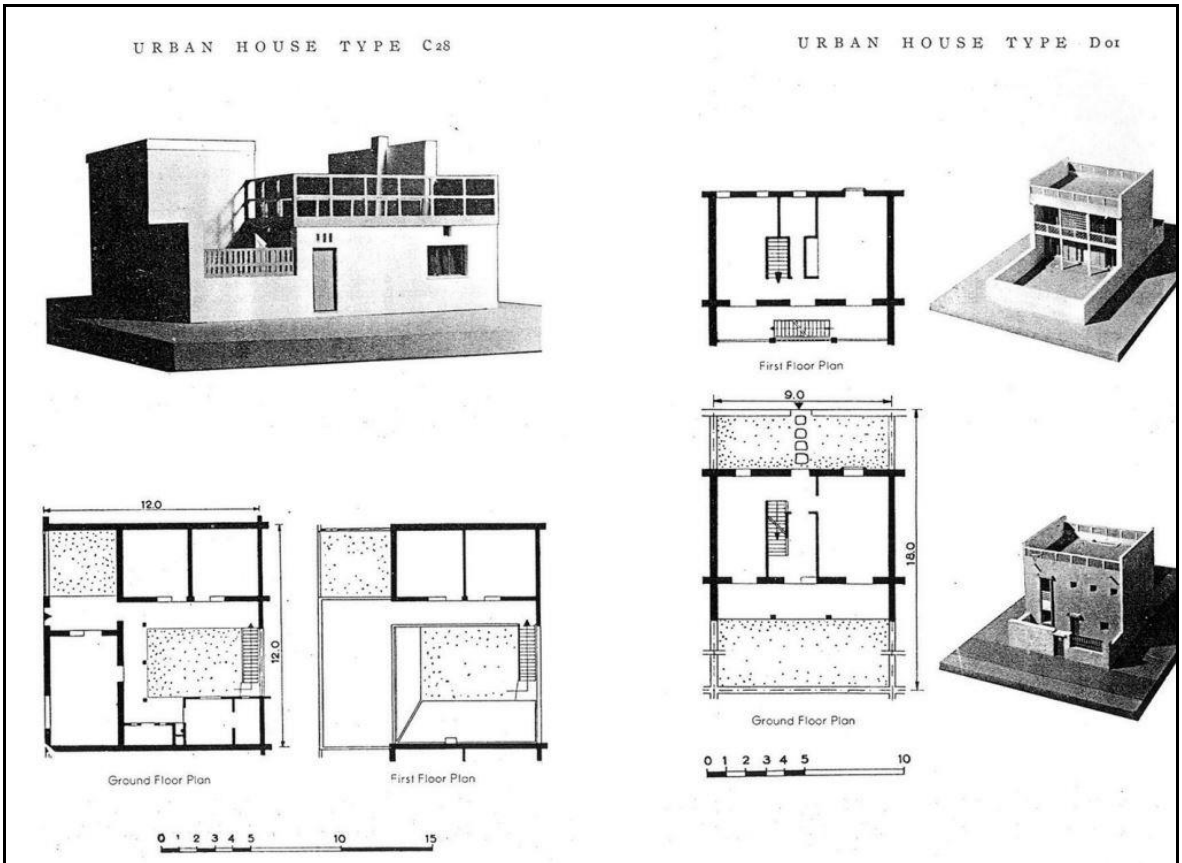


Figure 2.5 House Types in West Baghdad, DA, 1957. (Doxiadis Archives)a

However, after the coup/revolution of 1958 that was inspired by the Nasser one in Egypt, the new (Republic of Iraq) government cancelled his project in May 1959. Which pushed away the universalism Doxiadis advocated in his designs for. (Crinson, 2003).

Nevertheless, Doxiadis's company was still allowed to stay, and his design was partially built by Abdel Karim Qasim in 1959, the Iraqi prime minister at the time. One of the neighbourhoods that you can still see now a days that followed this plan is Madinat Al-Sadir (commonly known as Al-Thawra, translates to "the revolution"). It is one of the poorest life quality districts in Baghdad, and is considered a very low-income region of the city. The following (Figure 2.6) shows the plan of community sector in Baghdad.

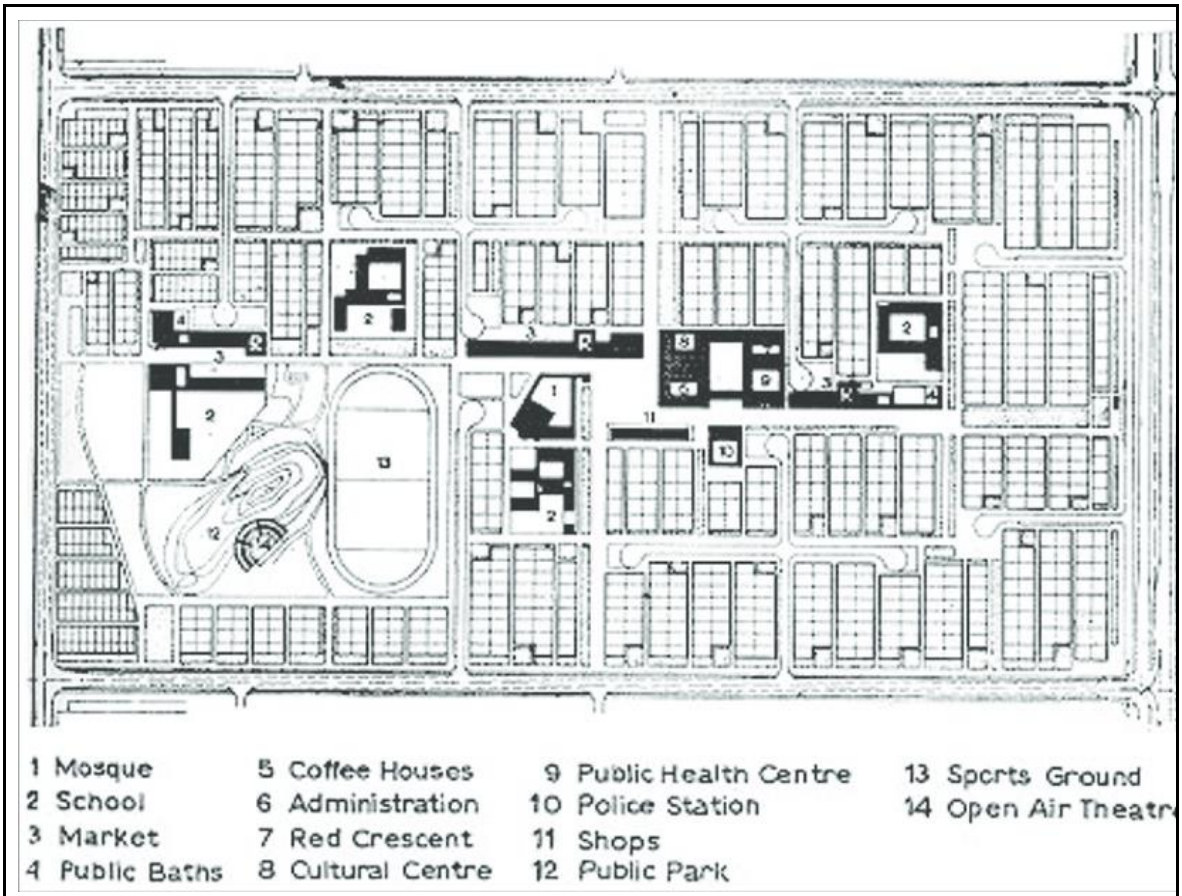


Figure 2.6 Plan of community sector in West Baghdad, Doxiadis Associates Master plan of Baghdad, 1958. (Doxiadis archives)b

The plan looks very similar to other modernist architects' designs of that period, it was not specific to Baghdad, and did not reflect the specific cultural demographics of the people who would be living there. Although, it did include some traditional elements, such as the coffee houses and public baths, and introduced new elements like an open-air theatre and public parks. However, when looking at the Doxiadis plan in general (Figure 2.4), and comparing it to a plan of Baghdad of that period (Figure 2.7), it is very easy to see that

they have nothing to do with each other, spatially when compared to other plans presented by other planners and firms that were more oriented towards Baghdad's organic growth as a city, which will be discussed later in this chapter.

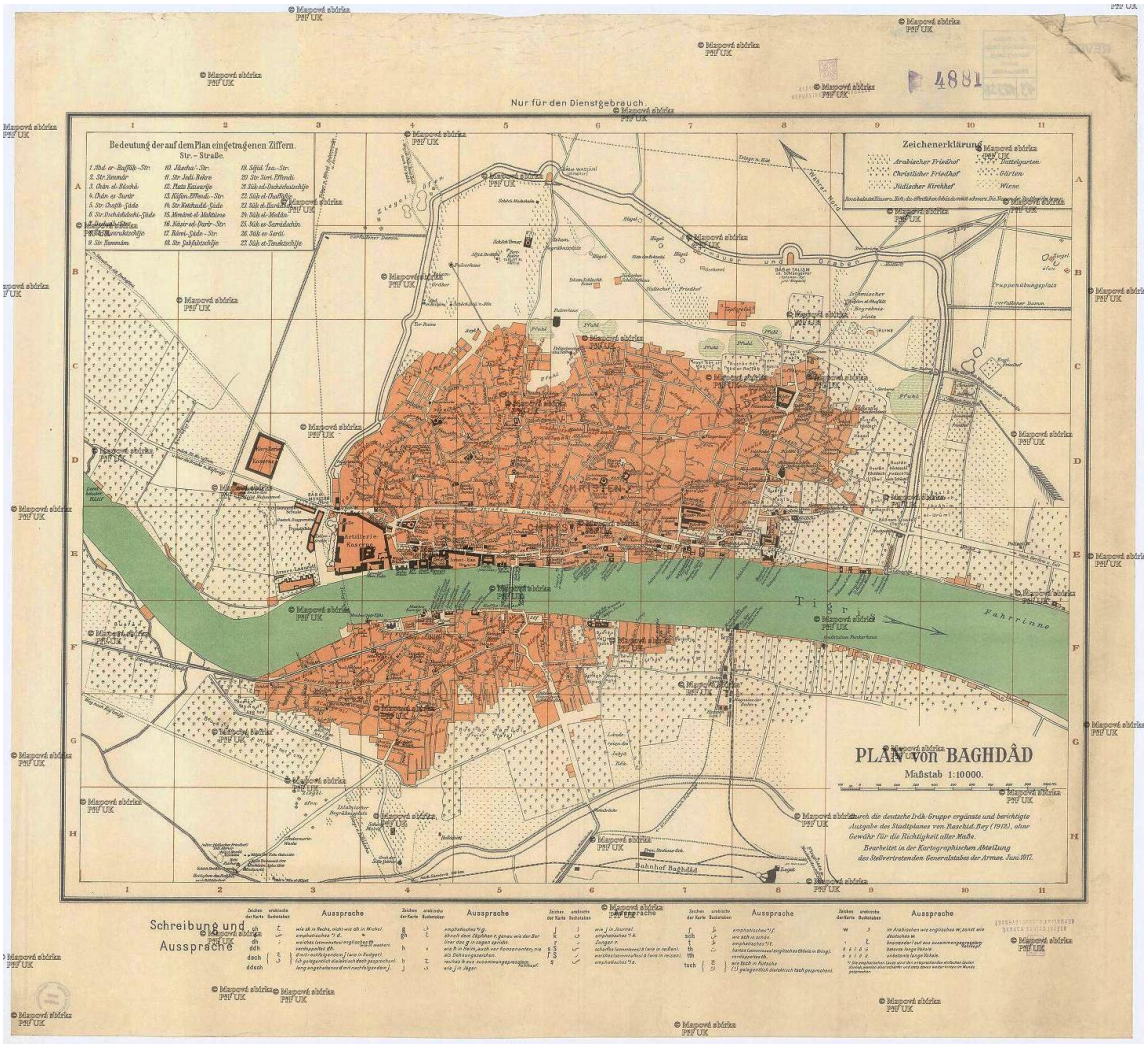


Figure 2.7 City map of Baghdad, year 1917, city plan, scale 1:10,000 (Charles University).

However, credit should be given to Doxiadis for his social engineering attempts of trying to put people from different ethnicities, cultural backgrounds, and religious beliefs into the same neighbourhoods, in order to have a more interconnected city. Nevertheless, he still failed at understanding the different ethnicities needs, the cultural backgrounds of these ethnicities, and most importantly, the climate of the city.

2.3.3.1 The "Republic of Iraq" era

After the 1958 coup/revolution, the new (Republic of Iraq) government had a very different approach to social politics, from the Hashemite regime. The new government was

leaning more towards socialist governments; they invited companies from the former Soviet satellite states, such as (the Czech Republic, Bulgaria, Eastern Germany, Hungary, Poland, and Romania) along with the former Yugoslavia.

3.3.3.2 Miastoprojekt plan

One company in particular Miastoprojekt, the Polish state firm was commissioned to make a master plan of Baghdad. And since they aligned with their state socialism and political economies that granted this Polish team to be permanently located in Baghdad in the 1960s and 1970s (Stanek, 2017). They, as well as planners who worked on Baghdad's master plan before them, were tasked of finding solution to the increasing housing problem in Baghdad. The increasing migrating population that forced the organic creation of slums that amounted to almost half of the buildings in Baghdad at the time.

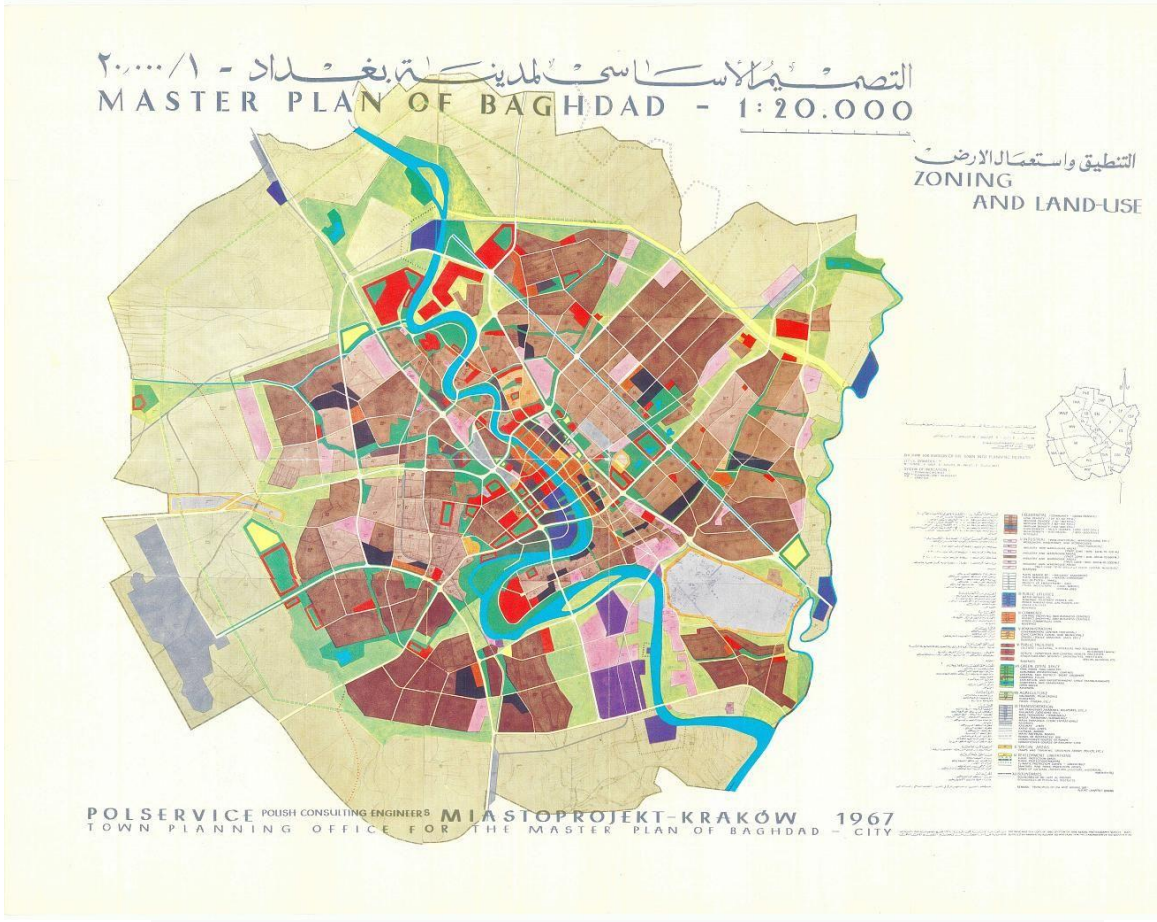


Figure 2.8 Master Plan of Baghdad" by Miastoprojekt Krakow and Polservice (1967) (Stanek, 2017).

They delivered their plan (Figure 2.8) in 1967, which also consisted of four volumes that worked on the first comprehensive survey plan of Baghdad. Which allowed them to avoid expropriations and large-scale demolitions of the historical centre, which

defined much of the 1950s. It also allowed them to experiment with planning concepts and do fine-tuning of their plans, since they were based in Iraq they were in direct contact with Iraqi decision makers, which lead to them reviewing and approving each and every step of the plan before it's built. The plan was flexible, with the possibility to correct and update it as new data was coming. As it also provided alternative predictions that dealt with various scenarios (Stanek, 2017).

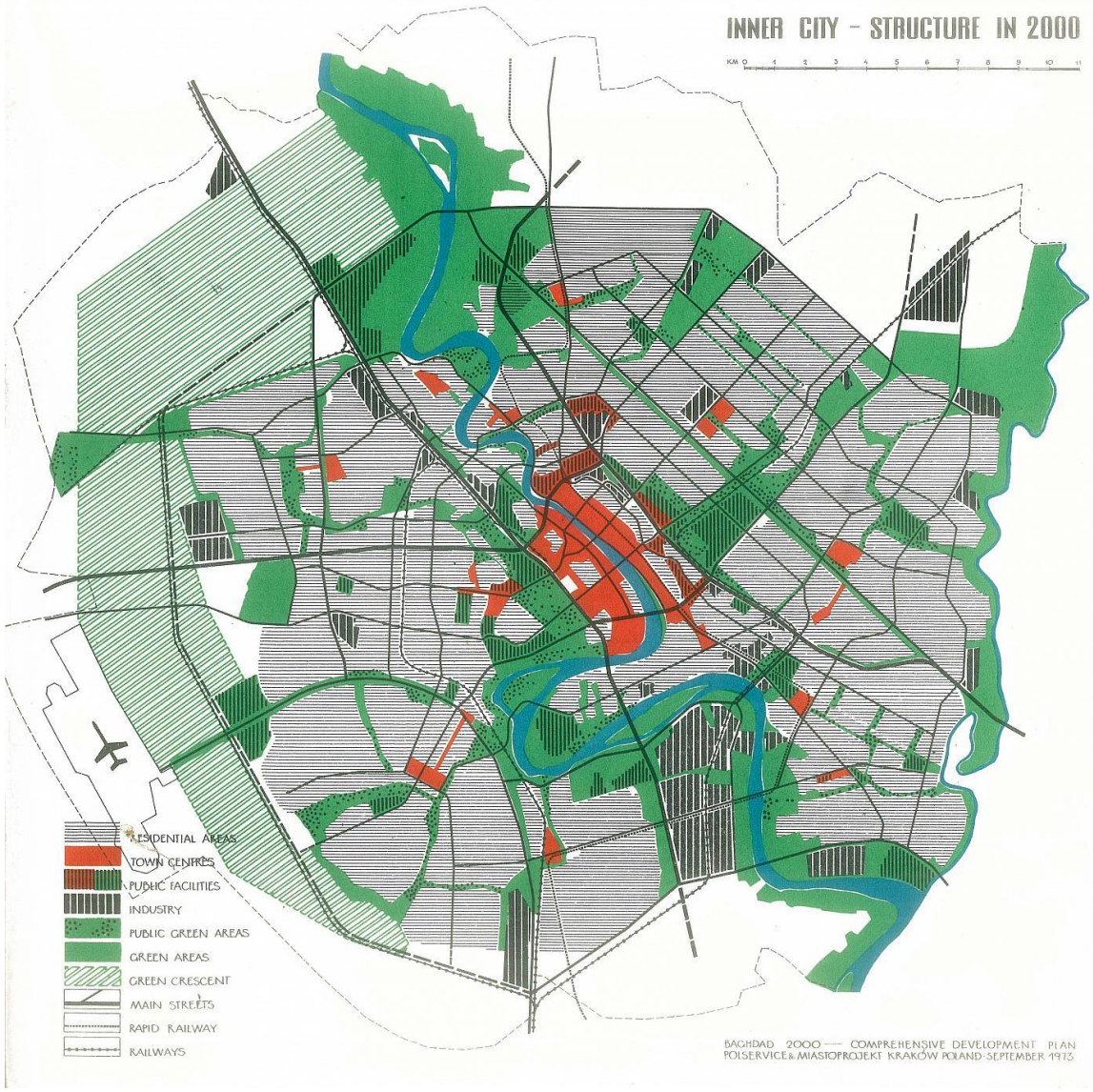


Figure 2.9 Comprehensive development plan for the vision of Baghdad in the year 2000, developed by Miastoprojekt 1973 (Stanek, 2012).

They recognised the historical parts of Baghdad in Rusafa (The east bank of the Tigris River) and Karkh (The west bank of the Tigris River) as commerce, and they understood these areas as for their multifunctional uses. Moreover, when looking at the

1973 plan (Figure 2.9) by Miastoprojekt for Baghdad in the year 2000 and the survey plan (Figure 2.11) by the JSSF (Japanese Consortium of Consulting Firms) in 1985 we can see that the Miastoprojekt plan guided the development plan of the city, spatially in the west and northeast of the city. It as well shows the urbanization of the city within the boundary of its municipality, and keeping the multifunctional belt around the Tigris bordered with the two belts of residential districts, which were subdivided into smaller entities that were planned to be self-sufficient with light industries and social facilities. As well as access to green areas were a key aspect of the planning process. (Figure 2.10).

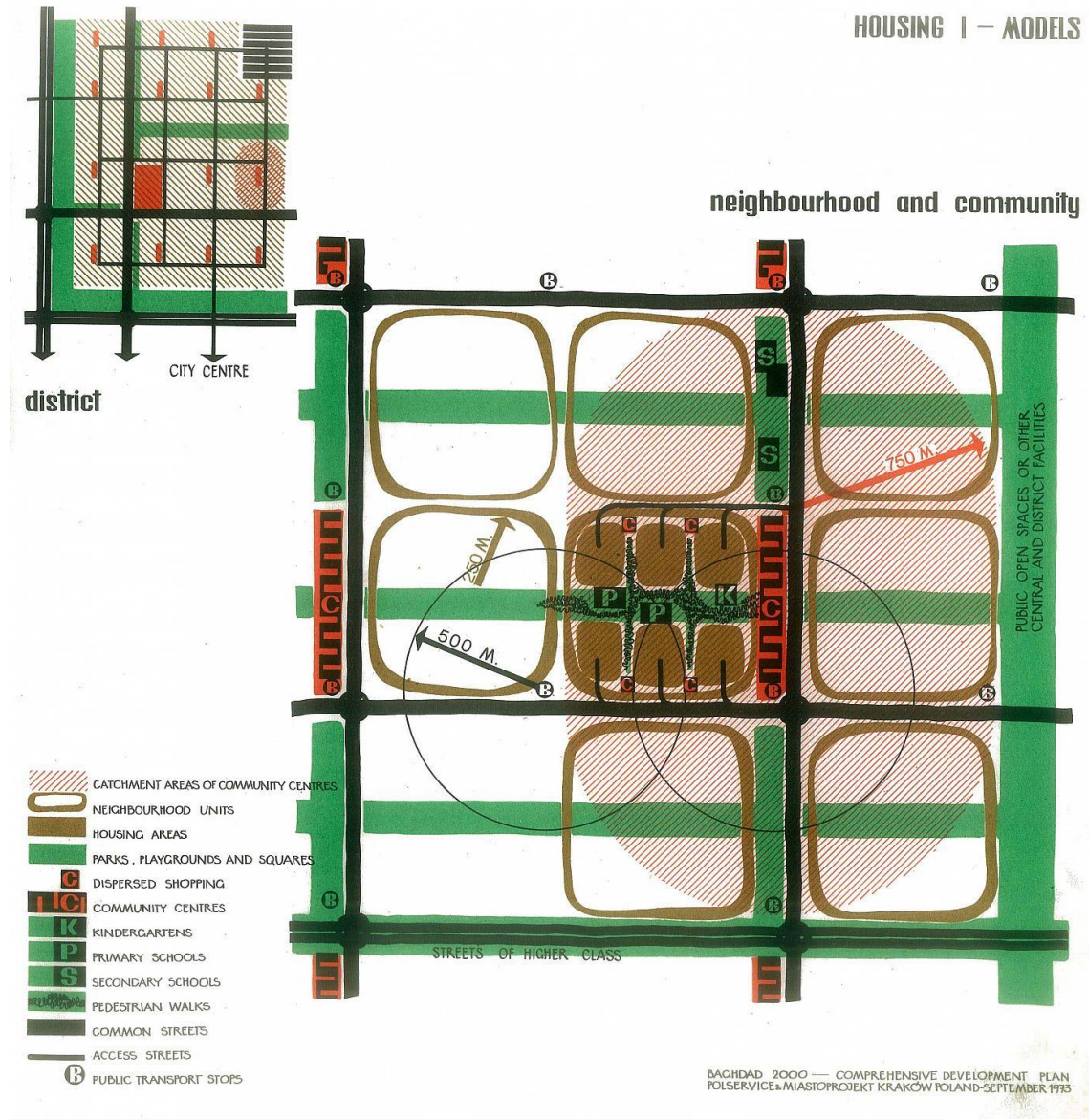


Figure 2.10 Housing models, in: Miastoprojekt—Krakow, "Comprehensive Development Plan for Baghdad" (Stanek, 2012).

Figure 2.11 Comparison of housing allocation as foreseen by the Miastoprojekt plan with the location of housing according to a land use survey in 1985 (Stanek, 2017).

Looking at (Figure 2.12) which shows the relation between the neighbourhood centres and the distance to the planned green areas that were functioning as to 'air [...] the city' along with the green belt that surrounded Baghdad. But looking the 1985 plan (Figure 2.11) by the JCCF we can see that the urban growth have disrupted the green belt in some areas, which disrupted the Miastoprojekt plan and overall, underwhelmed the distribution of urban fabric and the environmental performance of the plan (Stanek, 2017).

Figure 2.12 Distance between neighbourhood centres and the system of green spaces in the 1973 master plan (Stanek, 2017).

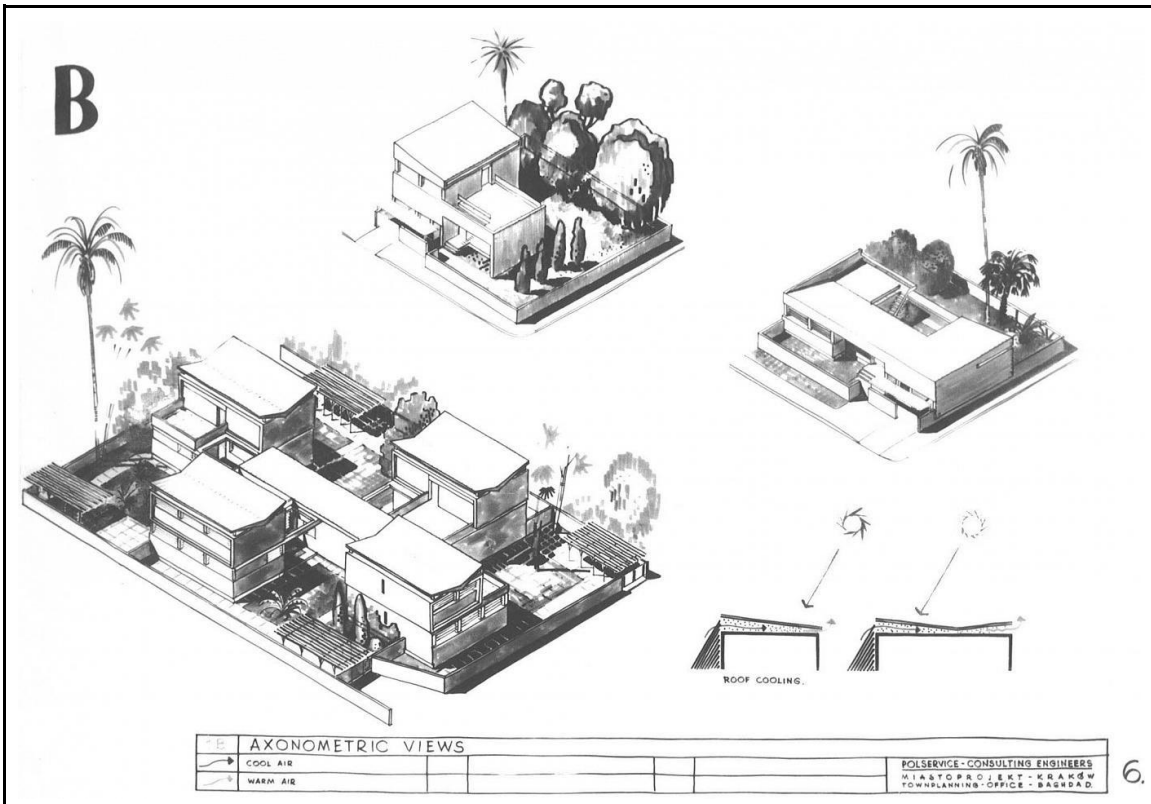


Figure 2.13 Residential Model Unit for Baghdad,1966. (Stanek, 2012).

Miastoprojekt thought about thermal comfort in and finding ecological/sustainable solutions their designs for the units (Figure 2.13) of housing in Baghdad, and the importance of green areas like the gardens. Which was a big leap from their predecessors (Doxiadis Associates), and (Minoprio & Spencely, and P.W. Macfarlane). They still failed, (in my opinion) to comprehend the ideas of the traditional houses (of Baghdad, Iraq, and the region) that used to exist in Baghdad. That provided year round relative thermal comfort with high attention to privacy.

2.3.4 Other architects and firms that were invited to Iraq

Other architects and planners from all over the world were called upon to participate in the planning of Baghdad during the period from the 1950s to the 1980s. Names such as F.L. Wright, who made the plan for greater Baghdad; Walter Gropius who built the University of Baghdad along with Boston-based firm The Architectural Collective; as well as Le Corbusier who designed the gymnasium and stadium in Baghdad. Other names included Gio Ponti, Alvar Aalto, and Jose Luis Sert.

2.4 Baghdad's region housing style

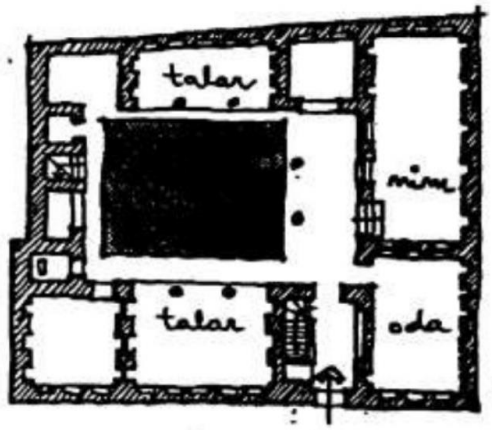


Figure 19. Ground floor plan of typical Baghdad courtyard house (the salamilk) (Schoenauer, 1981, page 42)

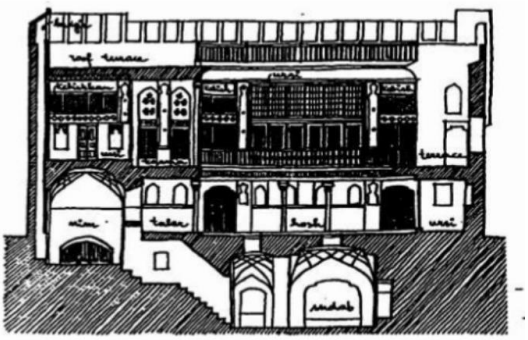


Figure 18. Section through the Baghdad house (Schoenauer, 1981, page 48)

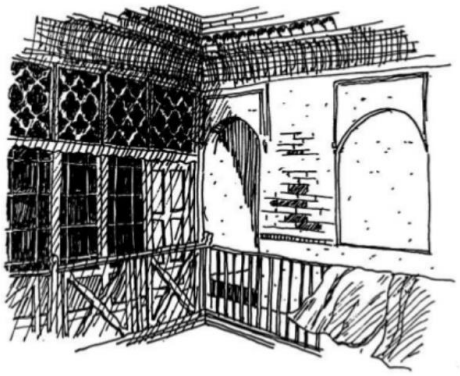


Figure 20. Baghdad: Northeast corner of courtyard (based on Schoenauer, 1981)

Figure 2.14 Ground floor plan, Section, and a sketch of a traditional Baghdadi house (Schoenauer, 1981).

Looking at old Baghdadi homes (Figure 2.14) we see the importance of the interior lobby of open space/garden which provided access to the outdoors with privacy for the inhabitants, along with the cooling functions of water elements, and multilayers of 'insulation' through shanasheel, and open corridors. In addition, the use of materials like mud bricks for building that give relatively cheap results, along with insulation benefits whilst keeping the identity of the city and the comfort of the inhabitants.

2.5 The Ministry of Construction and Housing and Public Municipalities (MCHPM) and the Planning Ministry in Iraq

The MCHPM and the Planning Ministry work as the two bodies regulating and developing strategies for current and future projects issued by the government. In addition, to finding solutions for the problems that are facing the country in regards to the infrastructure, housing, and investment opportunities.

During a 57 minutes interview with a senior engineer in the MCHPM (who has requested to remain anonymous), we discussed (in regards to the MCHPM and the Planning Ministry) and in relation to green areas; the current objectives, current and previous issues, current regulations and implementation issues, political and corruption effects, and the internal migration affect on the over densifying of Baghdad.

2.5.1 The history of the MCHPM and Planning Ministry

Before the 1990s, the MCHPM and Planning Ministry used to work as a resident engineer for foreign companies that used to in Iraq, which gave local engineers a great amount of experience that helped immensely after the 1990s economic embargo on Iraq. These engineers managed to continue the work in addition to building new project for the infrastructure of the country.

After the 2003 invasion, the MCHPM and Planning Ministry changed their strategy into depending on private investment as joined ventures between Iraqi and foreign companies. However, this new strategy failed miserably because of its unclear rules and the incompetence of the foreign companies, which were mostly companies that had nothing to do with construction or building, in addition to massive economical and administrative corruption.

2.5.2 Current objectives of the planning department in Baghdad.

The current objectives of the ministry of construction and housing, are delivering housing projects for the citizens of Iraq since it is the biggest concerns of the ministry, infrastructure such as schools, roads, bridges, etc. in addition to overseeing investment project around the country.

2.5.3 Current regulations implementations issues regarding green areas

There are regulations that control and specify the amounts of green and open areas in private housing and other types of buildings such as commercial or public services buildings. However, these laws and regulations are not being implemented on the ground by the municipal authorities.

Private houses started to be divided into smaller pieces and gardens are being built extensively. An example was given by the interviewee was “a house on a land with an area of 600 m^2 is being divided into 10 houses, creating each house into a 60 m^2, and in some cases there are even houses with 30-50 m^2 which leaves no space for gardens or green

areas". Which according to the regulations, a piece of land cannot be divided into less than 200 m² to have a house built on it.

However, with newer megaprojects, the planning department is seriously considering open and green areas. For example, 40-50% of the newly built city 'Basmaya' is open and green areas (including parks, public garden, streets, parking, and main squares), and it's being regarded as a successful project by the MCHPM which oversaw the planning process and put in place specific regulations to maintain a certain amount of public spaces.

2.5.4 Corruption's effect on the green areas.

There two situations when talking about the building in private gardens:

1. Building without a licence to build
2. Building with fraudulent schematics, in order to get the licence from the government officials, but since there is no overseeing of the construction to make sure everything is being built to code, these people continue to build differently from the licenced schematics.

Moreover, in most of the cases when the overseeing authorities do punish or control what people have built illegally, the overseeing authorities would come with forces and threatening power, in order to blackmail and persuade people into *paying ransoms* to keep their illegal housing. This in turn, hints at the large amount of corruption that is continuing to deteriorate the green areas in Baghdad.

2.5.5 The internal migration issues in Iraq and their effect on the over densifying of Baghdad.

The current migration structure in Baghdad is going as follows: people from other cities in Iraq migrating to poor neighbourhoods in Baghdad for security and economical issues, people who live in poor neighbourhoods are moving to slightly better neighbourhoods but with less people from other cities because of the cultural differences and safety concerns, and so on and so on, depending on the personal economical capabilities of people. This puts pressure on the amount of existing housing, and forces the building of newer housing since it is more appealing for owners of big houses to sell their gardens or lands for higher prices when the land is divided to smaller pieces. Moreover, since privacy is a main concern for Iraqis, which in general are used to relative 'luxury',

even if they are not very rich, they are still not used to sharing their own house or building with strangers, this is why there is not much vertical housing spreading.

2.5.6 Politics effect on the development and work of the MCHPM and the Planning Ministry

An important issue causing a lot of unproductivity, is that the two branches of government MCHPM and the Planning Ministry that control the development of Iraq in general and Baghdad in particular, are managed by two different political parties that are adversaries, with different spatial interests and strategies about how things should proceed. These two ministries are controlled with people who were put in power based on their loyalty to their political party or people in power, not on their competence. Which is why these people have little to no regard for regulations or laws, and they only care about their spatial and corrupt interests. An example of this the former minister of the MCHPM used to be a primary school teacher, and used to work as security guard for one of the people in the ruling party, who made him the director of MCHPM. This former minister had no idea about the works of MCHPM or the development strategies of Iraq. What he did do was he hired “by force” more than 300 people from his political party and friends with no experience in the field and spread them around the ministry, these people were usually a force of distraction that collects salaries without doing anything, only sometimes they would sign up on projects that would not be accepted regularly by the ministry or it’s engineers.

CHAPTER THREE: LITERATURE REVIEW ON THE BENEFITS OF TREES

3.1 Introduction

The main reason for choosing trees as a heating insulator of sorts, is that they are living organisms that don't store the heat nor it emits it in contrast to built structures, since the trees reflects a partial portion of the heat back to space, and uses the majority of the heat for it's Photosynthesis. This chapter will look into the benefits and functions of trees as environmental engineers and the benefits of green structures in cities, along with understanding the urban heat island effect on the thermal comfort for humans, and the way trees function to reduce the effect of urban heat island and increase the thermal comfort for humans, with looking at case studies of research that was done in Baghdad in relation to benefits of shade. While looking at the species that were recommended and found to be tolerant and suitable for the climate of Baghdad.

3.2.1 The urban heat island effect

Urbanization tends to gradually raise the temperatures of urban areas (cities) compared to the surrounding rural areas in a phenomenon known as the "Urban Heat Island" (UHI). (Figure 3.1). This phenomenon is mostly observed during night-time and calm weather conditions. The intensity of the UHI effect depends on the city's size, geographical location, and population, land-use distribution, urban structure, type of urban activities, and the absence or presence of vegetated green space and trees. The difference in the temperature of air between the rural landscape and the city canter can reach over 10°C however, it can be significantly reduced within the urban fabric by the presence urban green structures. These urban green structures and trees contribute to the enhancement of thermal comfort for humans in cities through mitigating the UHI effect that is caused by the modified land surfaces (paved and built areas), which increases the sensible heating environment, resulting from the absorption of solar radiation and the withholding of heat by the denser, drier surface materials (Hiemstra et al., 2017), This effect is called the Park Cool Island (PCI) effect, it describes the temperature difference between urbanized and vegetated areas that experiences public parks cooling effect. It's intensity depends on "land

cover, type of vegetation, tree species and coverage, park size and across seasons and weather conditions".

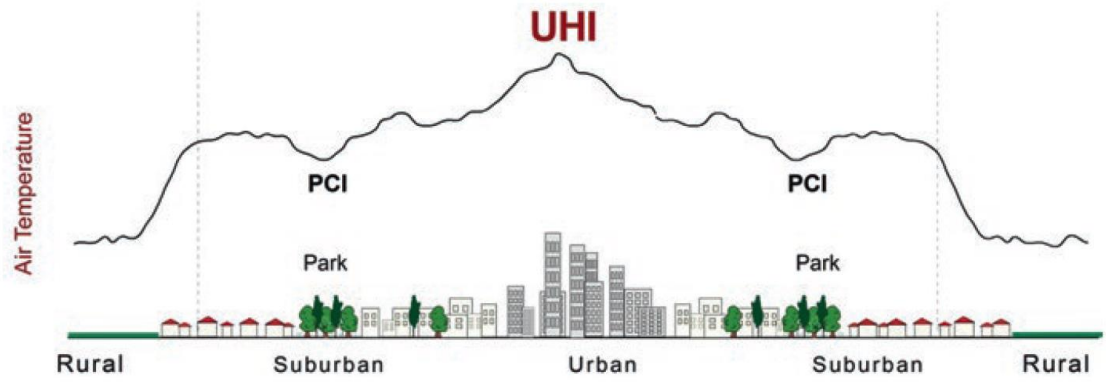


Fig. 2.1 Schematic transect illustrating the increased air temperatures in the urban area (Urban Heat Island: UHI), being maximal in the central urban district, in comparison to the rural area outside the city, and the cooling effect of parks (PCI) within the urban area (Figure courtesy of Dr. Zafrir-Reuven based on Oke 1987)

Figure 3.1 Schematic illustration showing the UHI effect in built areas having increased air temperature compared to rural areas. In addition, showing the difference between dense urban areas and areas with more parks and vegetated cover (Hiemstra et al., 2017).

3.2.2 Thermal comfort

According to the (ASHRAE standard, 2004), thermal comfort is "the condition of mind which expresses satisfaction with the thermal environment" it's influenced by the body and surrounding environment exchange of energy, spatially; radiation (radiant temperature from the sun for example), air temperature and wind speed, and sweat evaporation which is limited by humidity (Hiemstra et al., 2017).

Using indices such as the Physiologically Equivalent Temperature (PET), thermal comfort can be quantified through the assessment of various combined indices of thermo-psychological parameters with meteorological parameters. Considering temperatures in studies that were conducted in similar climates; 18-23°C as comfortable, 24-29°C as slightly warm, to 35°C as warm, and up to 41°C as hot and about that as very hot. (Figure 3.2). (Matzarakis et al., 1998). The health and functioning of people is negatively affected by thermal stress, especially old people, ill, and pregnant women, are more affected by heat stress (Matzarakis et al., 2009).

Table 1 Ranges of the physiologically equivalent temperature (*PET*) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo

PET	Thermal perception	Grade of physiological stress
	Very cold	Extreme cold stress
4°C		
	Cold	Strong cold stress
8°C		
	Cool	Moderate cold stress
13°C		
	Slightly cool	Slight cold stress
18°C		
	Comfortable	No thermal stress
23°C		
	Slightly warm	Slight heat stress
29°C		
	Warm	Moderate heat stress
35°C		
	Hot	Strong heat stress
41°C		
	Very hot	Extreme heat stress

Table 3.2 Physiologically Equivalent Temperature for different levels of thermal sensation and Physiological stress on humans (Matzarakis et al., 2009).

3.3.1 The Benefits of Trees as Environmental Engineers

The characteristics of urban areas are a large population density of humans and an extensive proportion of sealed surface (Samson et al., 2017)a. These thoroughly built areas are "often resulting in a fabric of dense street canyons and a lack of open, ventilated spaces." This results usually with a "high pollution levels". And according to (Fuller et al., 2007), access to urban green structures in cities creates positive effects on the health, spiritual and psychological well-being of the inhabitants of cities. Thus, the environmental quality of cities must be maintained and improved constantly, in order to make the cities

attractive and healthy places for their inhabitants. This maintaining and improving can be done by reducing water, soil, and air pollution, and urban green structures can be used as the core for controlling the levels of pollution and the enhancement of the physical environment. Which improves the general well-being of the inhabitants.

3.3.2 Benefits of Urban green areas.

Planting of vegetated green structures is one of the most effective ways to mitigate heat stress in urban areas (Gill et al., 2007) through urban forestation, it "can significantly moderate the intensity of UHI in cities" (Hiemstra et al., 2017). One of the most effective ways to lower the UHI effect intensity is by combining large green spaces in gardens and parks, with small green structures in a network covering streets and squares. PCI effect is usually generated by green areas through "two complementary mechanisms: *Shading* and *evapotranspiration*". (Hiemstra et al., 2017).

3.3.2.1 Shading

Shading plays a significant role in attaining thermal comfort for pedestrians by blocking a large amount of the incoming solar energy, which in turn reduces the exposure a person has to short-wave radiation that's coming directly from the sun, and the long wave radiation that's being emitted and reflected from built surfaces. This (meaning shading) of course reduces the heat stress on humans. With a large-scale trees shading, this can have an effect with a notable reduction in the air temperature (Figure 3.2), which in turn enhances the thermal comfort more (Hiemstra et al., 2017).

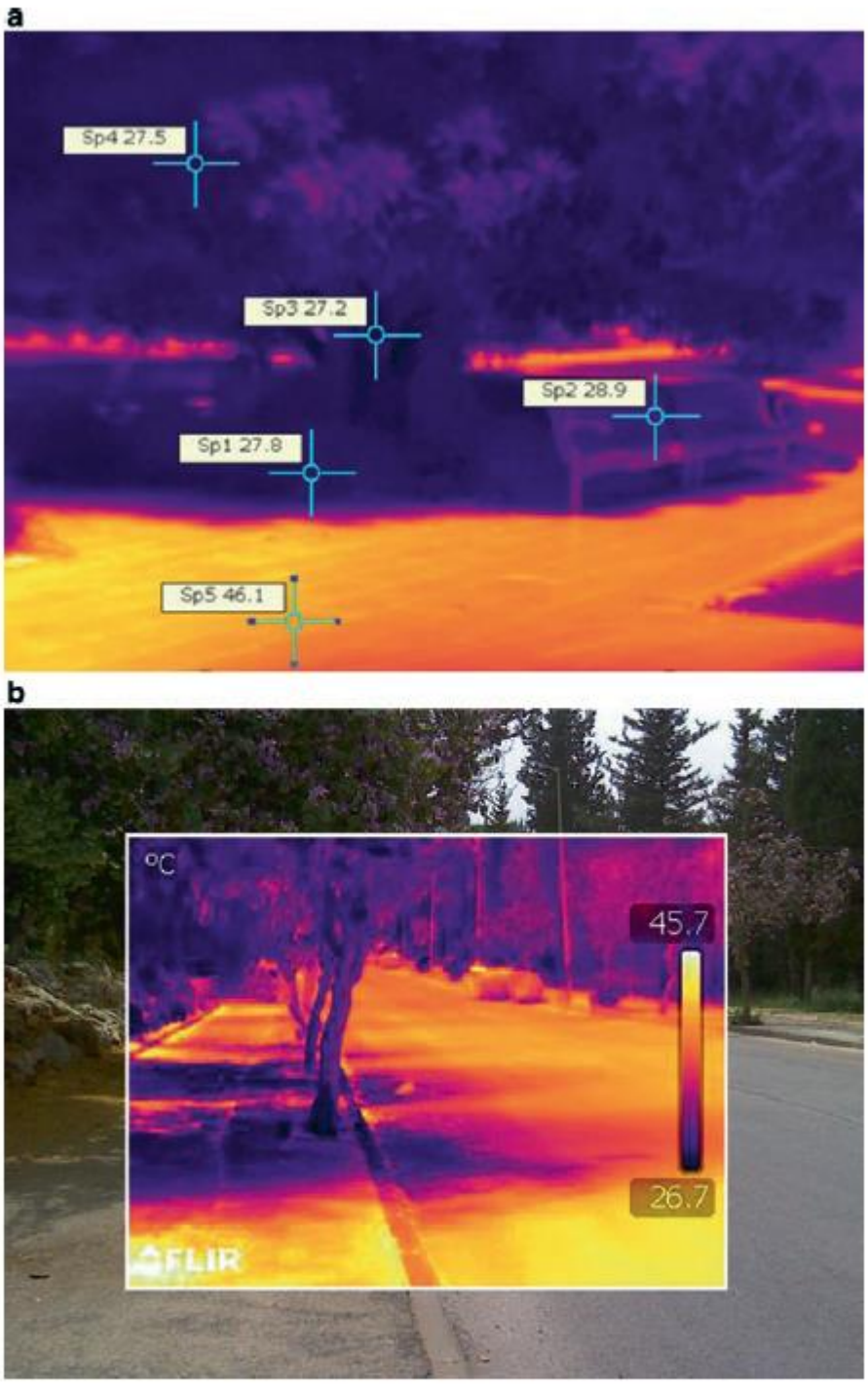


Fig. 2.2 Thermal infrared (IR) images indicating the daytime difference in radiative surface temperature between exposed and tree-shaded street paving in (**a**) Sydney, Australia (Reprinted with permission from Samuels 2010); and (**b**) a town in northern Israel. In both cases the surface temperature differences reach approximately 18 °C

Figure 3.3 Using thermal infrared cameras, we can see the effect shading has on sealed surfaces (streets and paved sidewalk), and how the difference can reach approximately 18 Celsius degrees (Hiemstra et al., 2017).

3.3.2.2 Evapotranspiration

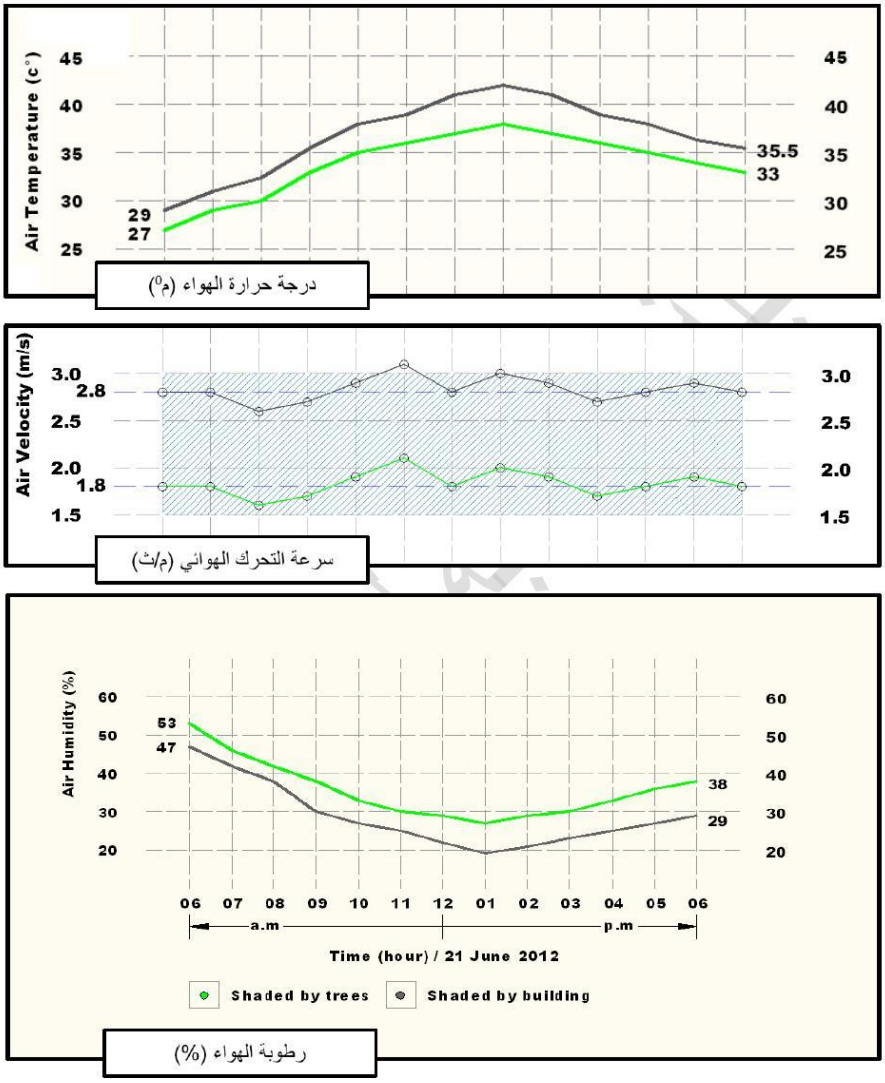
Evapotranspiration reduces air temperature as well through transpiration from tree canopy, and vegetated ground cover through the increasing of air humidity taking part of the air temperature by the evaporation of water taken from the ground by the roots of the trees and plants. the tree leaves' multi-tiered structure are also beneficial because of their effective shading, which does not increase the radiative temperature of the tree canopy. This cooling effectiveness process depends highly on the availability of soil water, and it's limited by the biomass and volume of the tree, these parameters are crucial in determining the provided amount of shade. Which is why "tall trees with large, dense crowns are much more effective than smaller trees" (Hiemstra et al., 2017).

3.3.2.3 Air quality and its relation to trees.

Plants are living organisms that functions by breathing (taking) carbon dioxide and other air pollutants, including particulate matter and other various gaseous pollutants, stores it in the plants biomass and in the soil (Samson et al., 2017)b. This depends on the species of the plant and its ability to store the carbon below or above ground, and the plant's size; with smaller trees often being within the low category of storing capacity, while large trees with large canopies that are fast growing tend to have an extended root system that is able to have a high capacity in storing carbon dioxide. According to (Samson et al., 2017)c looking at studies comparing rural and urban areas, rural areas showed lower carbon dioxide concentration when there was vegetation, in comparison to urban areas.

3.4 The Value of Shading, Case Study in Baghdad

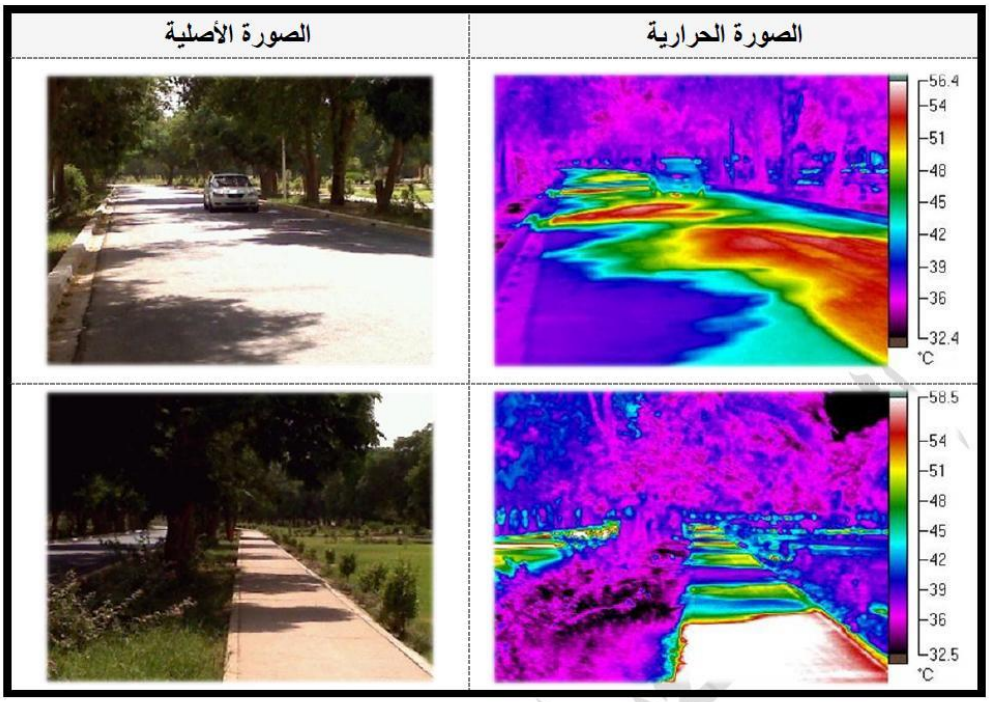
According to a study (Al-jawadi et al., 2014) conducted in Baghdad in June of 2012, the temperature of built surfaces (in this case asphalt) decreases 20-22.5 Celsius degrees (Figure 3.4) when shaded by trees, the air temperature under the shade of a trees is at least 2 Celsius degrees lower than the air under the shade of a buildings within the same area and surface, and humidity is 8% higher in the air that is shaded by trees that the air that is shaded by a building (Figure 3.4). The heat comfort temperature was reached in areas shaded by trees, however the area shaded by a building was within the uncomfortable temperatures during the hours (12:00, 13:00, 14:00), (Figure 3.4). This study was conducted on the 21/June/2012 from (06:00-18:00).



شكل (5) قراءات دورية لدرجة حرارة الهواء، التحرك الهوائي، الرطوبة فوق الرصيف في حالتي التظليل (بالأشجار أو الكتل البنائية)

Figure 3.4 . Observations results of the study conducted in the university of Baghdad on the 21/June/2012 from 6 am until 6 pm on areas shaded by trees marked by green lines and areas shaded by buildings shaded by dark brown. On the top is the air temperature differences during observation the day measured in Celsius degrees, in the middle is the air velocity in meters per seconds, and on the bottom is the percentage difference of air humidity during the observation day (Al-jawadi et al., 2014).

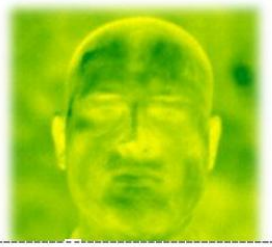
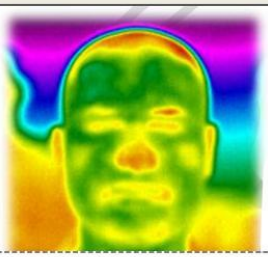
They (Al-jawadi et al., 2014) also captured and measured different vegetated and built surfaces with different finishes using a thermal camera to show the thermal difference between the absorbed and stored temperature in the mass of these surfaces and their capacity to emit the heat energy to passer-by pedestrians and their thermal comfort level (Figure 3.5).



الشكل(6) الصور الحرارية لعناصر الشارع الحضري (موقع الأختبارات)ويظهر فيها الفرق الحراري بين عناصر الشارع الحضري البنائية والنباتية كما يلاحظ الفرق بين العناصر والسطوح المظللة والمكشوفة / المصدر : الباحث

Figure 3.5. On the left are the normal images, on the right are the thermal images taken on the study site on the university of Baghdad, showing the thermal difference between the built and vegetated elements, showing the difference as well the thermal difference between shaded and unshaded areas. All temperatures are in Celsius degrees. (Al-jawadi et al., 2014).

The study also captured the face of a volunteer using the thermal camera under the shade of *Albizia lebbeck* tree and under the sun with no shade, from 8:00 am until 4:00 pm to show the amount of temperature that is being absorbed from the atmosphere around the face and on the skin (Figure 3.6) since the face is a central zone of the human body that plays an important part in the observing of feeling of thermal comfort.

Time	Thermal evaluation of skin temperature	
	under the shade of tree row	under the sun
10 am		
Difference	+2 °C	

الشكل(7) (نموذج) التقييم الحراري لمستخدمي الرصيف في الشارع الحضري/ المصدر: الباحث

Figure 3.6. Thermal difference evaluation of a volunteer at 10:00 am on 21/June/2012 on the study site in the university of Baghdad, showing to the left the face shaded by a row of trees, and on the right the face directly under the sun (Al-jawadi et al., 2014).

3.5 Analysing the amount of shade that could reached by planting main streets in Baghdad.

The study by (Al-jawadi et al., 2014) concluded that there's approximately *800 kilometres* of main public streets, with the use of *Albizia lebbeck* as a sample for their calculations, they assumed a five meters distance between each planted tree and on the two sides of the streets, *320,000 trees* could be planted just on public streets, found that approximately 39,000,000 refrigeration tons (RT) per day of thermal energy would be blocked from reaching horizontal surfaces with shading only (assuming that 10% of the sun thermal energy goes to the soil, and 20% of the sun's thermal energy gets reflected back to space with the tree's leaves canopy). And an approximate 6,000,000 (RT/Day) of thermal energy gets blocked through transpiration, all together an approximate *45,000,000 (RT/Day)* of thermal energy would get blocked from horizontal surfaces by the planting of 320,000 trees on the main public streets of Baghdad.

3.6 Literature review summary

From this chapter, and with the literature evidence, we can say that the amount of sealed surface, in relation to green areas, the number of trees, and the type of vegetation is directly linked to the temperature of surfaces and air in urban areas (subchapter 3.2.1). And that thermal comfort of humans is directly related to their physiological well being (subchapter 3.2.2). In addition to the thermal mitigating benefits of trees and green areas, they as well work as environmental engineers in reducing air, soil, and water pollution

(subchapter 3.3.1). And that urban green structures can reduce and mitigate heat stress caused by UHI through *shading* and *evapotranspiration*, and it's highly more effective with larger-scale trees (subchapter 3.3.2). Carbon dioxide and other air pollutant can be decreased by using fast growing trees with large canopy that are able to store these pollutants above or below ground (subchapter 3.3.2.3). When looking at case studies in Baghdad, it was discovered that surface temperatures can be highly reduced by using the shade of trees, as well as air temperature and increasing air humidity, in addition to decreasing heat stress on pedestrians, and by decreasing sealed surface, it is possible to have a more comfortable environment throughout the day (subchapter 3.4). Moreover, by planting the main public streets in Baghdad, it is possible to block/mitigate *45,000,000* (RT/Day) of thermal solar energy from being reflected at people or surfaces, or being remitted back to the city during night-time (subchapter 3.5).

CHAPTER FOUR: METHODOLOGY

The strategy was composed of two methods, the first method was to map and study the changes that have occurred throughout the specified years in the city of Baghdad, the second method was to understand the people's perception and understanding of these changes, their interests and priorities when it comes to green areas, the second method was conducted through a questionnaires as a part of a survey.

4.1.1 Methods used to analyse the city's green structure changes throughout the years (2000-2010).

To better understand the changes that have happened to the green structures in Baghdad in a quantitative way, the tracking was done through mapping and turning raster images into vector shape files that are more accurate for calculating things such as the different land categories and their areas, and the amount of trees, and the amount of changes that have occurred through the specified years.

4.1.2 Choosing the study sites.

Since Baghdad is quite a large city, I choose representative sectors of the Baghdad that include a representative sections / blocks of an area to take as sample, To help understand and evaluate how much of the public (agricultural areas, parks) and private (gardens) green areas have been transformed into buildings or simply lost due to neglect. Moreover, the criteria that was used in order to specify which areas were chosen were as follows:

1. A relatively wealthy neighbourhood. For this character, the site of *Al-Mansour* was selected.
2. A part of the city that is close by to the river area with. (Middle-income neighbourhood). For these characters, the site of *Al-Safina* was selected.
3. An area that shows the spread to the edges of the city and the internal migration to Baghdad spread onto the green agricultural belt that used to exist. (Poor neighbourhood). For these characters, the site of *Al-habibiya* was selected.

4. A historical commercial area. For these characters, the site of *Al-Sinak* was selected.

4.1.3 Details of the chosen sites

This subchapter will detail a brief history of the chosen sites, along with their location within the city of Baghdad, Iraq.

4.1.3.1 Al-Mansour

4.1.3.1.1 Brief history

Al-Mansour named after the creator of Baghdad "Al-Mansour" this neighbourhood is located on the middle/western part of Baghdad (Figure 4.1), (Figure 4.2), (Figure 4.3), on the western side of the Tigris River (Karkh). It can be recognised through its large houses, wide streets, and borgouse class (historically) families. Initially created in the 1950s by the Iraqi Development Board for the expansion of Baghdad, and as a representative of a modern Baghdad to the world. Royal family members inhabited it during the Hashemite period. It continued to spread with smaller sections of the neighbourhood with land for houses ranging from 500 to 2000 m². After the 2003 war, Al-Mansour did not get affected as other parts of Baghdad, and now a days is one of Baghdad's luxurious neighbourhoods with large houses and a main commercial centre for clothing and entertainment.

This neighbourhood was chosen for the economic level of its residents, in addition to type of housing it has.

4.1.3.1.2 Site location

Figure 4.1 Map of Baghdad with Al-Mansour highlighted in red. Image not to scale. Google Earth 2018.

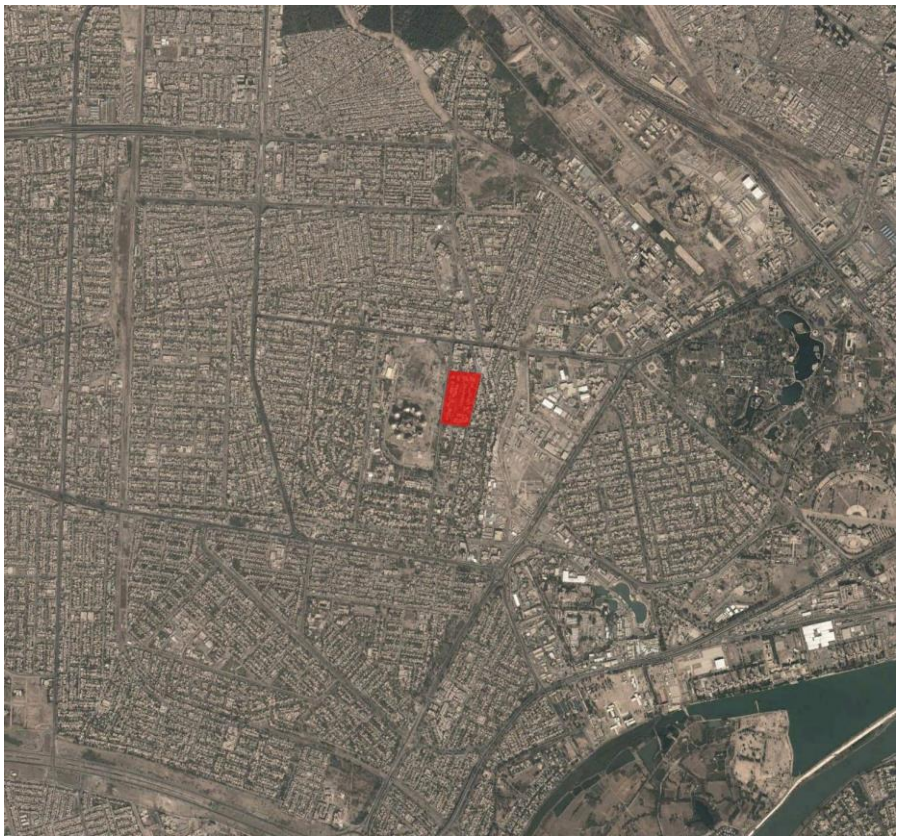


Figure 4.2 Aerial image of Al-Mansour, with the study site highlighted in red. Image not to scale. Google Earth 2018.

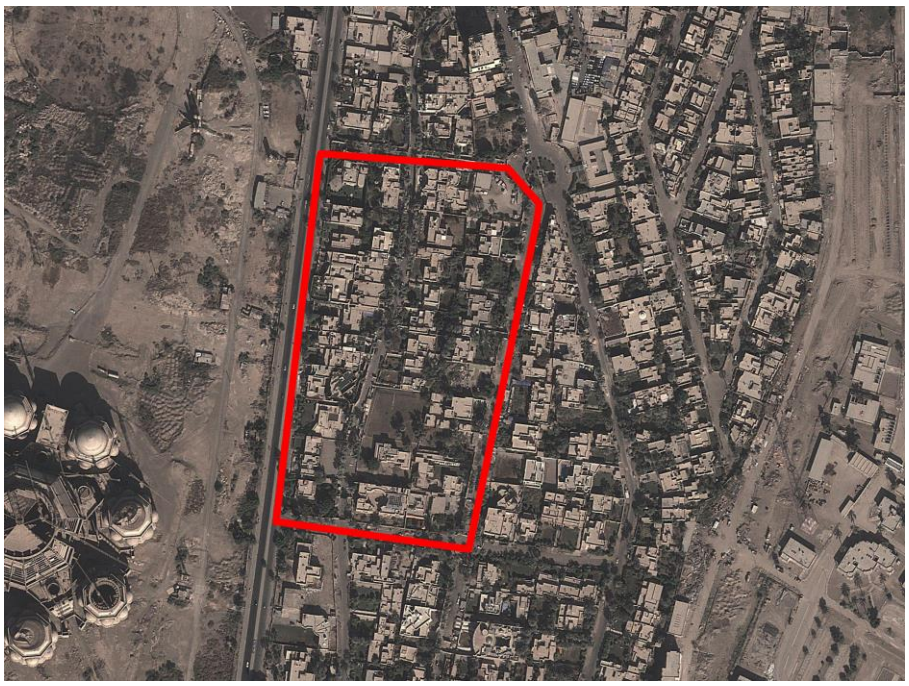


Figure 4.3 Aerial image of Al-Mansour study site bordered with the colour red. Image not to scale. Google Earth 2018.

4.1.3.2 Al-Safina

4.1.3.2.1 Brief history

A neighbourhood located within Al-Aadamiyah, north of Baghdad on the eastern bank of the Tigris River (Rusafa). Its name Al-Safina, translates to 'the ship' in refers to ships that used to dock on its shores for trade coming from the north and south of Iraq, along with ferries that used to get people to cross to the other side of the Tigris river (Karkh).

Al-Aadamiyah started as a graveyard in and later to a small village nearby, grew with time, and shrunk again through wars and events that happened to it. Initially created during the Abbasid dynasty in the 760s, but it was an outside part of the Circular city of Baghdad. It had large Orchards and well established busy markets. And with the initial urban development during the 1930s to 1958 it was a destination place for military officers, and bourgeois class to move into with the building of new areas of Al-Aadamiyah (including Al-Safina) with designs of villas with private gardens, unlike to the older Baghdadi style of the older parts of the Al-Aadamiyah with interior yards. Currently (Al-Safina) is inhabited by middle class families.

A neighbourhood within Al-Safina was chosen to be part of the study for the importance of urban structure development in this part of Baghdad, it's relation to the river, and the inhabitants economical class (level of income) of this site.

4.1.3.2.2 Site Location

Figure 4.4 Aerial image of Baghdad, with Al-Safina study site highlighted in red. Image not to scale. Google Earth 2018.

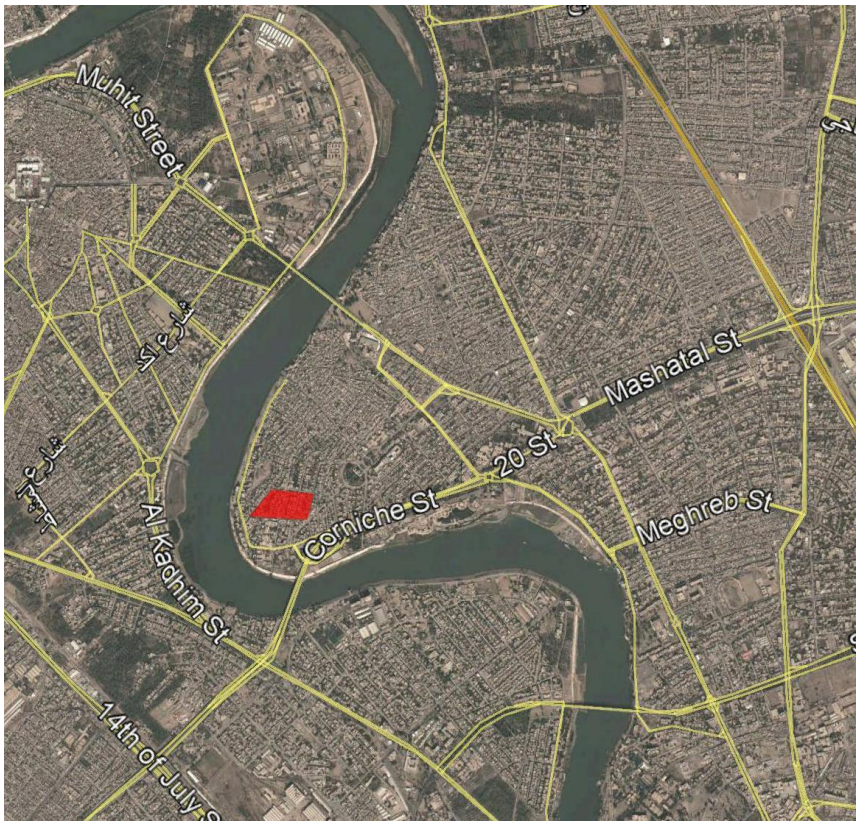


Figure 4.5 Aerial image of Al-Aadamiyah, with Al-Safina study site highlighted in red. Image not to scale. Google Earth 2018.

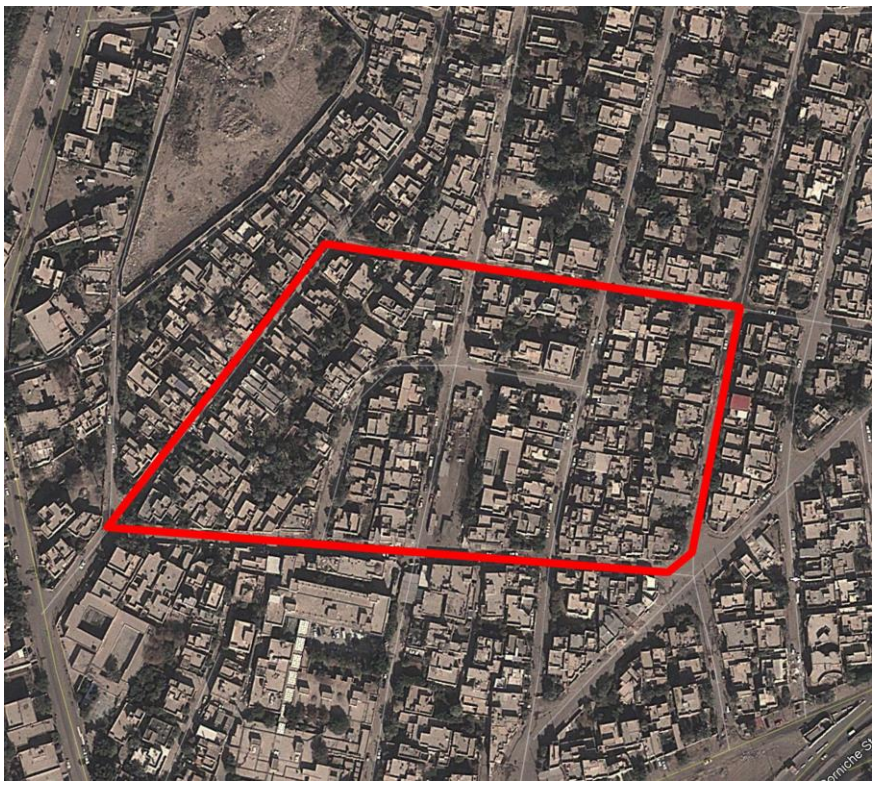


Figure 4.6 Aerial image of Al-Safina study site bordered with the colour red. Image not to scale. Google Earth 2018.

4.1.3.3 Al-Habibiya

4.1.3.3.1 Brief history

Located in the eastern part of Baghdad and the Tigris River (Rusafa), created as part of the Miastoprojekt master plan of Baghdad, to be part of the solution for the high migrating population into the city. Created initially in the 1960s-1970s, to be partially agricultural in order to be part of the *green belt* of Baghdad. After the 2003 war in Iraq, its agricultural area transformed into private housing through illegal and unlicensed building.

4.1.3.3.2 Site location

Figure 4.7 Map of Baghdad with Al-Habibiya highlighted in red. Image not to scale. Google Earth 2018.

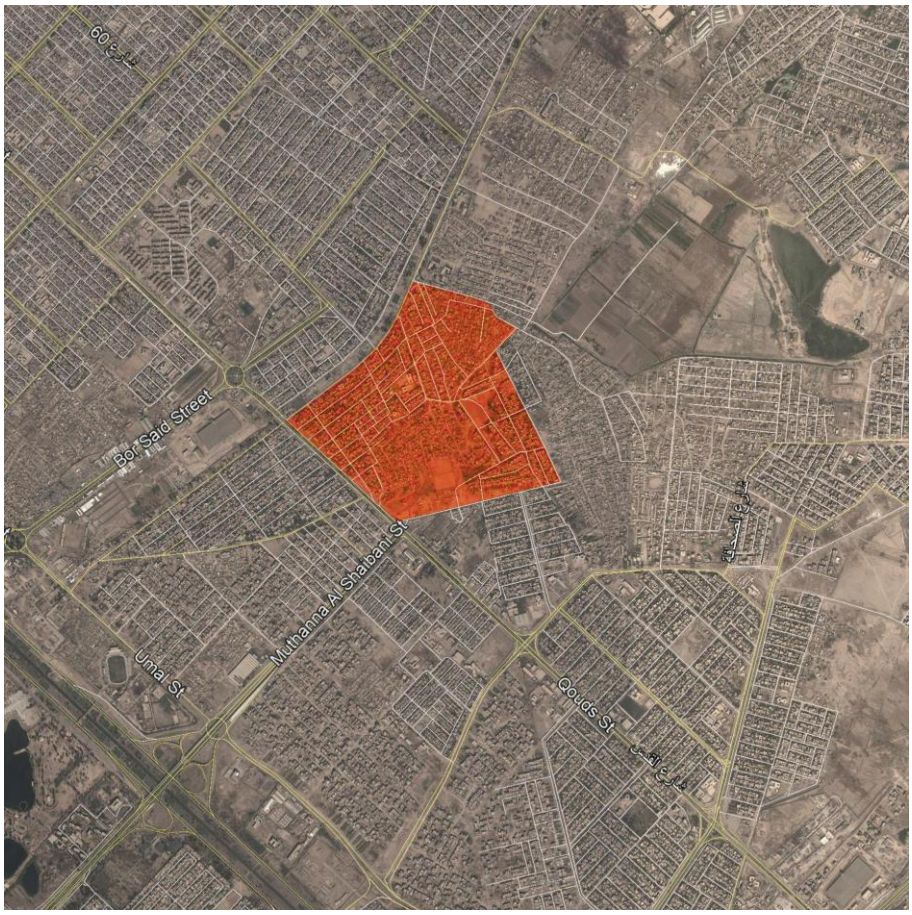


Figure 4.8 Map of Al-Habibiya with the study site highlighted in red.

Image not to scale. Google Earth 2018.

Figure 4.9 Aerial image of Al-Habibiya study site bordered with the colour red. Image not to scale. Google Earth 2018.

4.1.3.4 Al-Sinak

4.1.3.4.1 Brief history

Located in the middle of Baghdad on the eastern side of the Tigris (Rusafa) (Figure 10), (Figure 11), (Figure 12), It used to be called "Mahallat Al-Shatt" which means the "beach neighbourhood" in relation to its location next to the Tigris river. Created during the Abbasid dynasty to function as an agricultural land and farms to support the circular city of Baghdad. Later it was renamed to "Senek" which means "flies" by the ottomans because there was many flies from the farms. During the first half of the 19th century, the first houses and shops were being built there, with Baghdadi style of building mud bricks, shanasheel, and narrow alleys. Later after the 1950s with the new modern urbanism plans for Baghdad, the neighbourhood changed dramatically, commercial shops took over and spread through it, in addition to the destruction of the old buildings, and building with new modern materials and styles.

Currently it is Iraq's most important market for car parts and accessories. Being purely commercial and its urban structure is highly dense with shops, and streets sellers.

4.1.3.4.2 Site Location

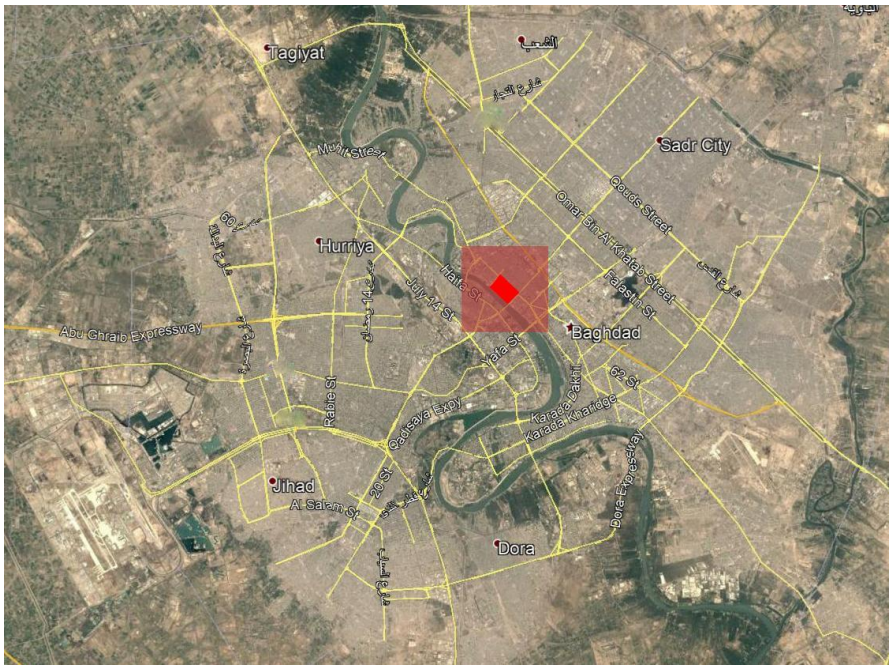


Figure 4.10 Aerial image of Baghdad, with Al-Sinak study site highlighted in red. Image not to scale. Google Earth 2018.

Figure 4.11 Aerial image of Al-Sinak study site highlighted in red. Image not to scale. Google Earth 2018.

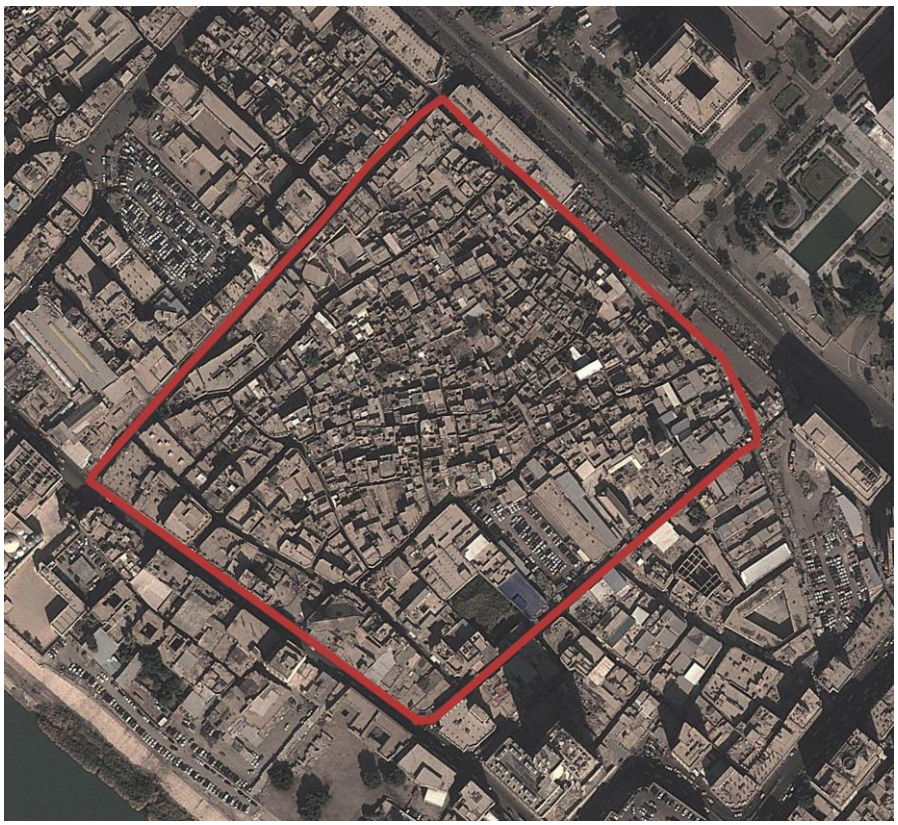


Figure 4.12 Aerial image of Al-Sinak study site bordered with the colour red. Image not to scale. Google Earth 2018.

4.1.4 Choosing the time frame for the gathering of satellite images

To get a relatively accurate data of the areas, and to have a clear view of the changes that have happened through 2000-2010, and according to the availability of satellite images, the frame of reference in time was as follows:

1. 2002: the era before the Saddam Hussein government removal.
2. 2004: the era after the Saddam Hussein government removal.
3. 2010: six years after the systemic control by the new governments systems.

4.1.5 Mapping and analysing the four selected sites for the time reference.

After choosing the four representative sites, and the time frame for the work, georeferenced images were downloaded using *Google Earth pro v7.3.2* and *Smart GIS v2018,* and later analysed using *ArcMap v10.6.1* to measure, map, and calculate the changes that have occurred in the land categories (green areas, build areas, agriculture, streets, empty lots, open areas) through the chosen time frame. (Appendix 1) contains a detailed description of this procedure.

4.2 Questionnaire development, administration and analysis

To understand how the people interact with the city, there was a need to understand how they see it. This warranted the creation of a survey (Appendix 2) to be distributed throughout the social media networks such as (Facebook, WhatsApp, and Telegram).

4.2.1.1 The information that was gathered in the survey and extracting the data from it

The survey was created with the intent to gather statistical data to understand the way people view the city, and how or if they see the difference in green structures and the amount of trees through the years, and whether if it's connected to the rising temperature of the city, the amount of storms, and the peoples psychological and thermal comfort. Also it explored the willingness of the people to participate in campaigns to plant and maintain trees and green areas in their neighbourhoods.

4.2.1.2 The creation of the questionnaire

The survey questionnaire was created using the free service of Google Forms, and it was linked to a Google Sheets file, for ease of use and to see the results of the survey in an interactive way, and to be able to create charts to represent the data.

Originally, the questionnaire was made in the Arabic language, since the targeted audience are native Arabic speakers. After the end of the survey, a copy was made of the original Google sheets file to work with, this new copy will be referred to as "Survey Results". The original answers file was saved unedited for the record and it will be referred to as "Original Survey Results".

4.2.1.3 Distribution of the questionnaire

The created questionnaire was distributed through Facebook pages and groups that are related to the residents of Baghdad, starting with pages that are related to architecture, agriculture, and the environment, but also focusing more on pages that are related to day-to-day life things where it's more possible to reach more broad audience sample. Later on, the survey was distributed through messaging apps groups within Telegram and WhatsApp with groups that are related to the residents of Baghdad as well. Moreover, people seemed to enjoy the questionnaire, and some people were sharing it further with their friends and relatives.

The questionnaire was firstly sent out on 26/Nov/2018, with the first result timestamp is at (11/26/2018 18:04:29) and the last result timestamp is (12/15/2018 22:25:19). On the 16/Dec/2018 at 00:00:00 the questionnaire was set to not receive any more responses in order to start working on analysing the received responses data.

4.2.1.4 Translation of the results

Since the survey and its results were all in Arabic still, the "Survey Results" file was edited in order to translate the questions and the results, using the 'Find and Replace' which can be found in the 'Edit' menu. By using the mentioned tool, the results were translated by putting the Arabic answer or question as text in the 'Find' part of the prompted window, and the English translation were put as a text in the 'Replace with' part of the prompted window, and pressing the 'Replace all' button, and repeating this process for all the answers and questions of the google sheet file "Survey Results".

4.2.1.5 Creation of the charts in the Survey Results file

Spatial analysis were done using the (Data/Table pivot) feature in google sheets, taking the gender and the age to get summarized tables about the data, to be turned into bar charts that were imported to the thesis file.

In addition, an add-on with the name of 'Advanced Summary by Awesome Table' was added to the google forms file to have a quick visual comparison when choosing to filter specific parameters.

The charts were created by selecting the specific range of answers, and inserting a 'Chart' from the 'Insert' menu. The chart type was chosen as 'Combo chart'. A title was added to each chart to make it easier to read and understand,

The charts were imported to the Google document through (Insert\Chart\'From Sheets…') to have it as an interactive chart in the document in case of any updates that need to be done later on.

4.2.2 The Characteristics of the Survey

After the creation of the survey, and the publishing of it through the mentioned social media platforms that relate to residents of Baghdad, *323 people* responded to the survey with and the majority of the respondents were males 222 (68.7%) and females were 101 (31.3%). (Figure 4.13).

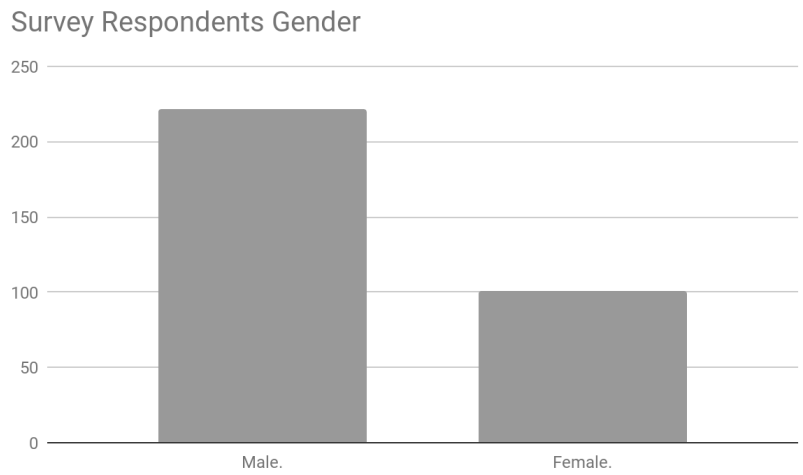


Figure 4.13 Survey responders genders.

The age groups of the respondents were as follows; 12-18 years old were 5 respondents (1.5%), 18-30 years old respondents were 111 (34.4%), 31-45 years old respondents were 117 (36.2%), and 46-70 years old respondents were 90 (27.9%). (Figure 4.14)

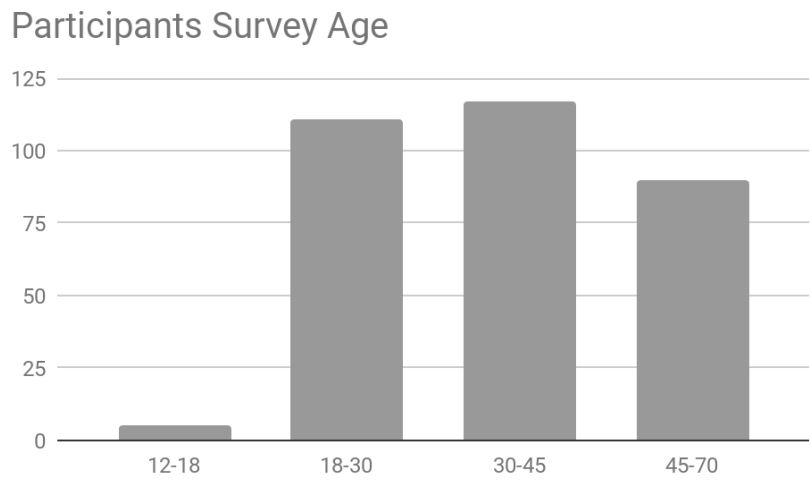


Figure 4.14 Survey participants age group (grouped).

The education level of the respondents were as follows, there were 4 (1.2%) respondents with a Primary education level, there were 32 (9.9%) respondents with a High school education level, there were 287 (88.9%) respondents with a University education level (Figure 4.15).

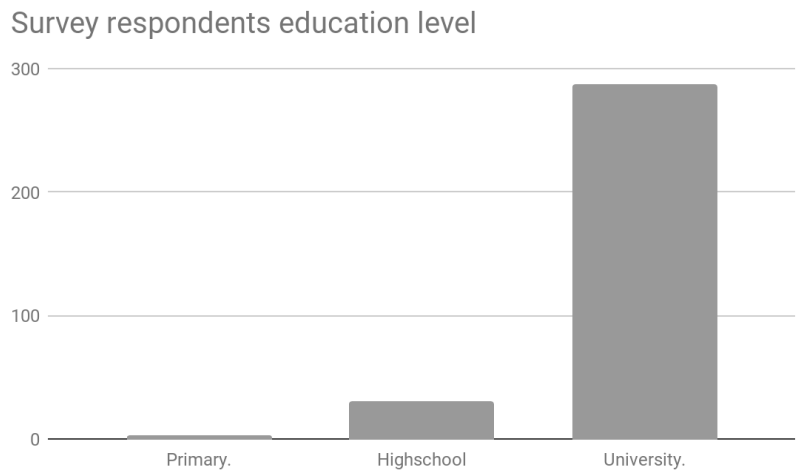


Figure 4.15 Survey participants education level.

Majority of responders (85.2%) were from people who are, or have been a resident of Baghdad. (Figure 4.16).

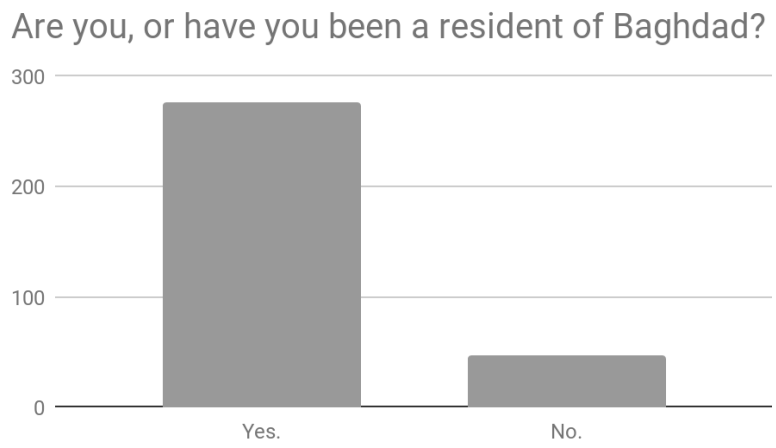


Figure 4.16 Whether the survey participants are living within in Baghdad or not.

CHAPTER FIVE: RESULTS

This chapter will look into the results of the two methods mentioned in the previous chapter.

5.1 Mapping Results

After transforming the images into georeferenced data, and mapping the different landscape categories in the four selected sites, through selected period (2002, 2004, and 2010) the following results were found in relation to each site:

More detailed map analysis can be found in (Appendix 3), and the different land categories values that were mapped in tables in the (Appendix 4).

5.1.1 Al-Mansour

The (Figure 5.1), (Figure 5.2), (Figure 5.3) show that have occurred in Al-Mansour study site, these are the results that were found in relation to this site:

1. The amount of green areas have decreased 9.69% throughout the specified time period. (Figure 5.4).
2. The built areas have increased more than 8.92% during the specified time period. (Figure 5.5).
3. The number of trees decreased from 131 in 2002, to 90 in 2004. However, it recovered to 159 tree in 2010. (Figure 5.6).
4. Streets and empty lots stayed the same during the specified time period. (Figure 5.7).
5. Buildings area composed 44.4% of the total case study area in 2002, by 2010 it increased to 49%. (Figure 5.7).
6. Gardens area composed 46.3% of the total case study area in 2002, by 2010 it decreased to 41.7%. (Figure 5.7).

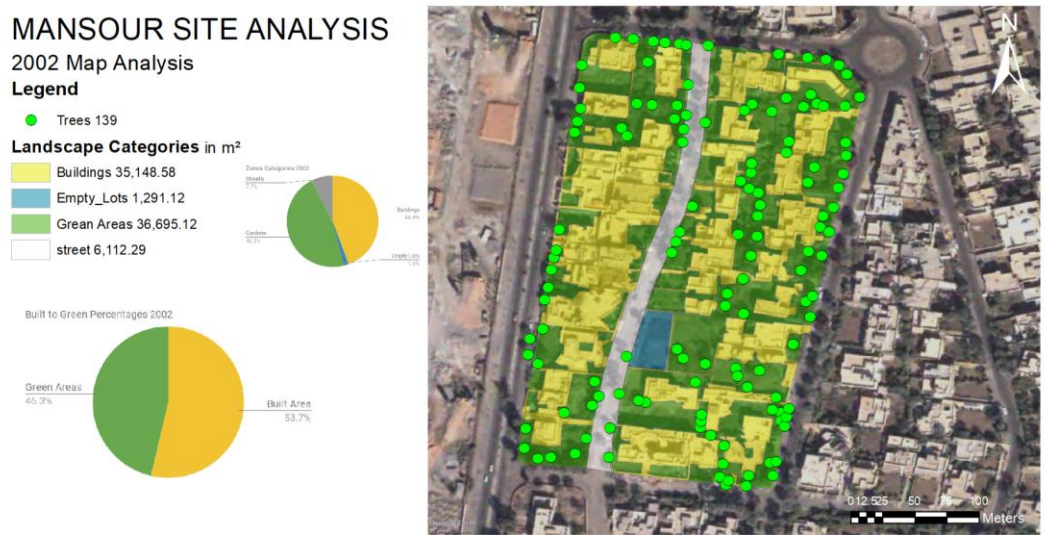


Figure 5.1 Map analysis of Al-Mansour in the year 2002.

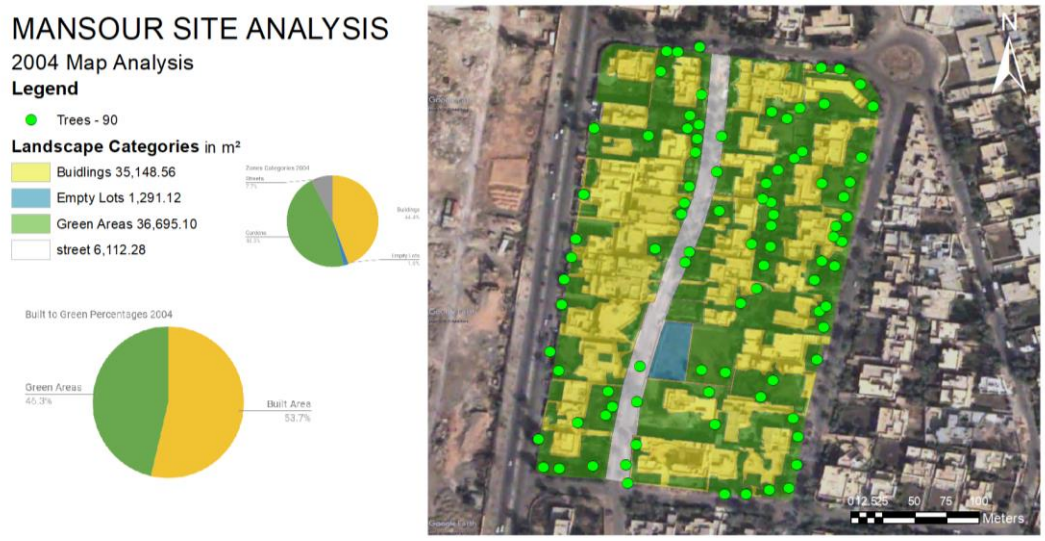


Figure 5.2 Map analysis of Al-Mansour in the year 2004.

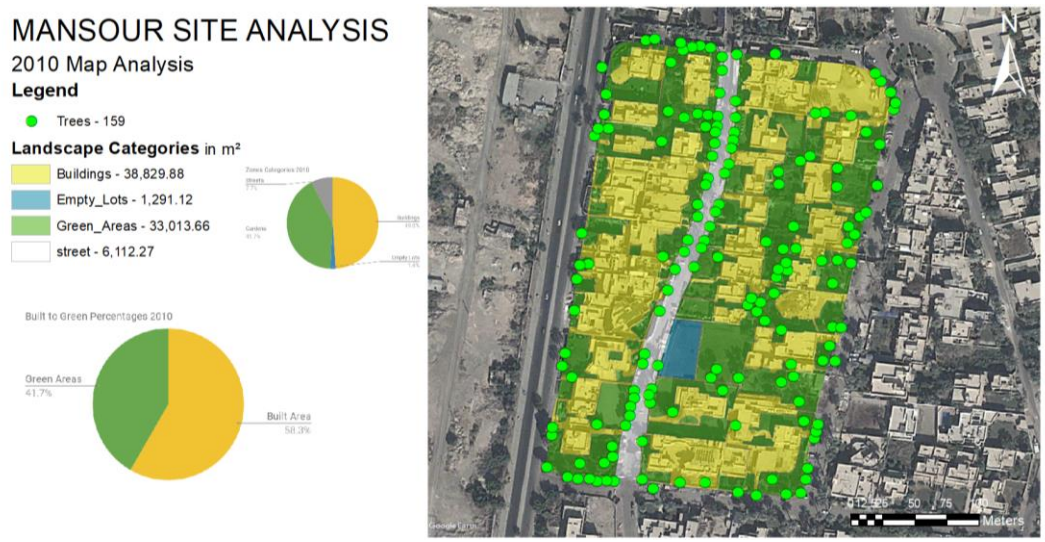


Figure 5.3 Map analysis of Al-Mansour in the year 2010.

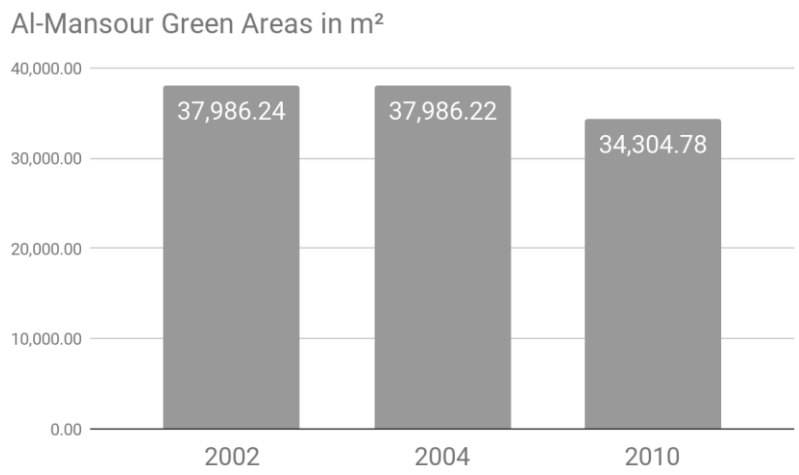


Figure 5.4 Green areas changes during the years (2002, 2004, and 2010) in Al-Mansour study site in m².

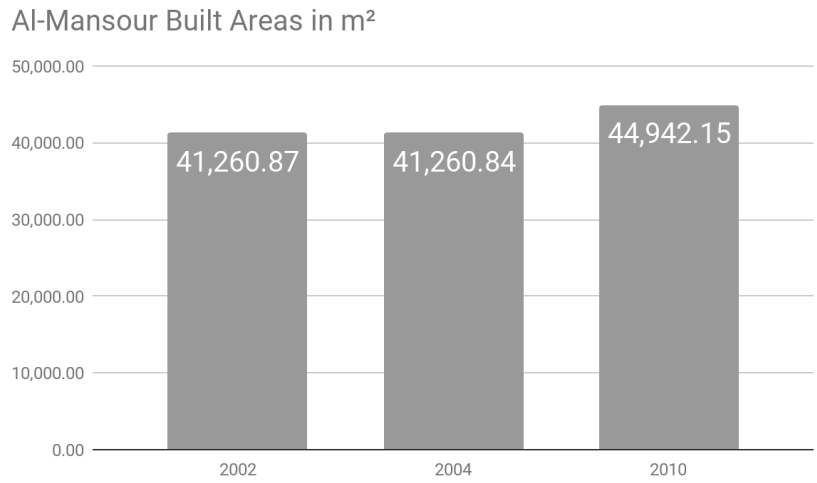


Figure 5.5 Built areas changes during the years (2002, 2004, and 2010) in Al-Mansour study site in m².

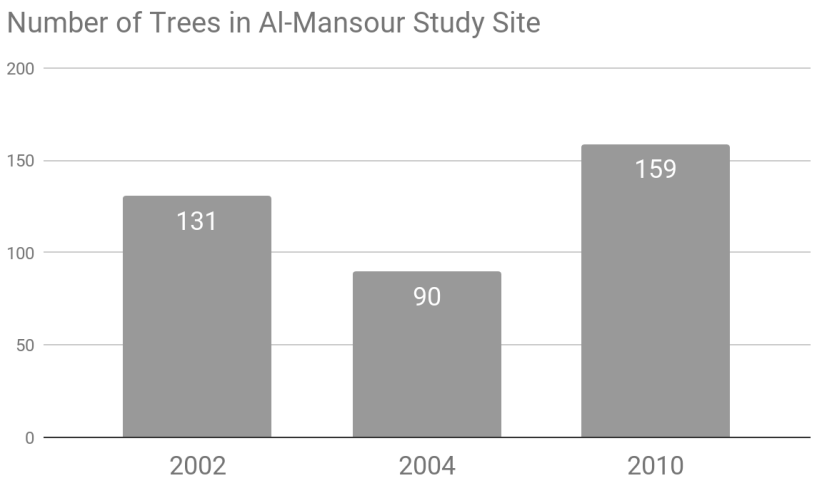


Figure 5.6 Number of trees changes during the years (2002, 2004, and 2010) in Al-Mansour study site.

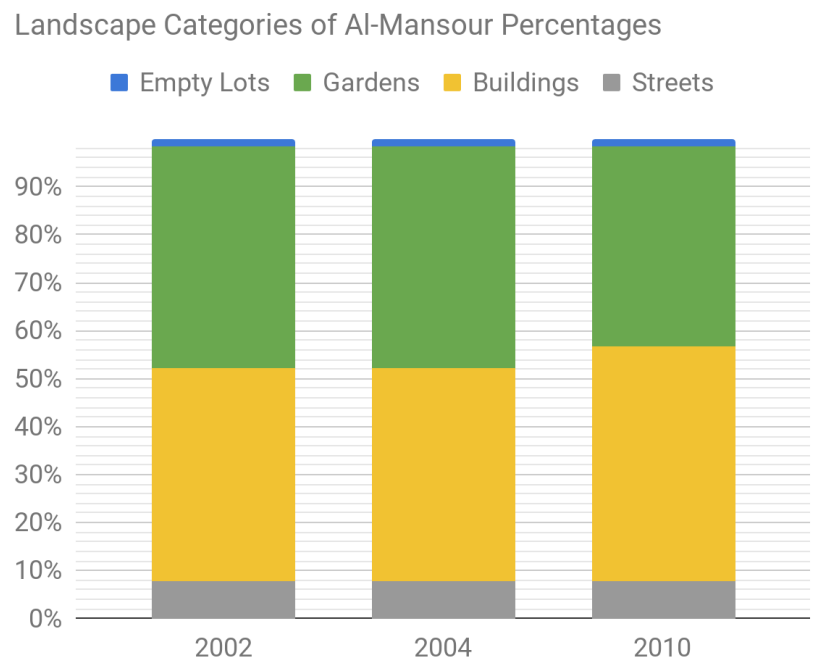


Figure 5.7 Changes in the land categories percentages during the years (2002, 2004, and 2010) in Al-Mansour study site.

5.1.2 Al-Safina:

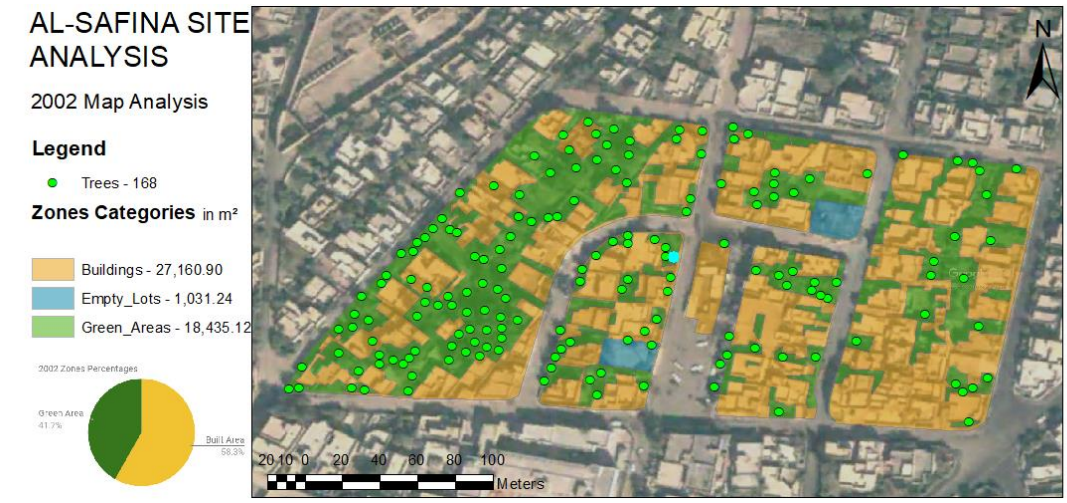


Figure 5.8 Map analysis of Al-Safina in the year 2002.

Figure 5.9 Map analysis of Al-Safina in the year 2004.

Figure 5.10 Map analysis of Al-Safina in the year 2010.

The (Figure 5.8), (Figure 5.9), (Figure 5.10) show that have occurred in Al-Safina study site, these are the results that were found in relation to this site:

1. The green areas have decreased 20.88% throughout the specified time period (Figure 5.11), green areas went from being 41.75% of the neighbourhood urban cover in 2002, to 33% of the neighbourhood urban cover in 2010. (Figure 5.13).
2. The built areas have increased 14.96% throughout the specified period of time (Figure 5.12) and the built area increased from being 58.25% of the neighbourhood urban cover in 2002, to 67% of the neighbourhood urban cover in 2010. (Figure 5.13).
3. The amount of trees have decreased 33.9% from 168 to 111 through the specified period, (Figure 5.14).

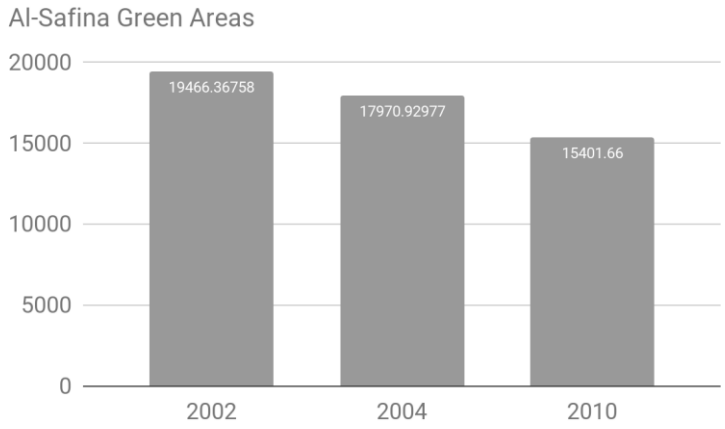


Figure 5.11 Green areas changes during the years (2002, 2004, and 2010) in Al-Safina study site in m².

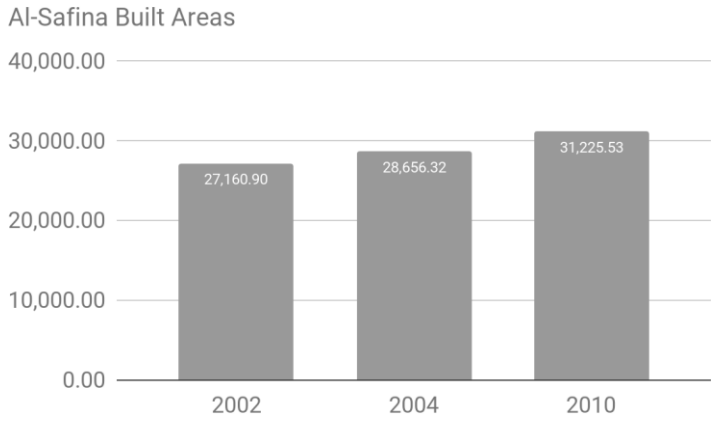


Figure 5.12 Built areas changes during the years (2002, 2004, and 2010) in Al-Safina study site in m².

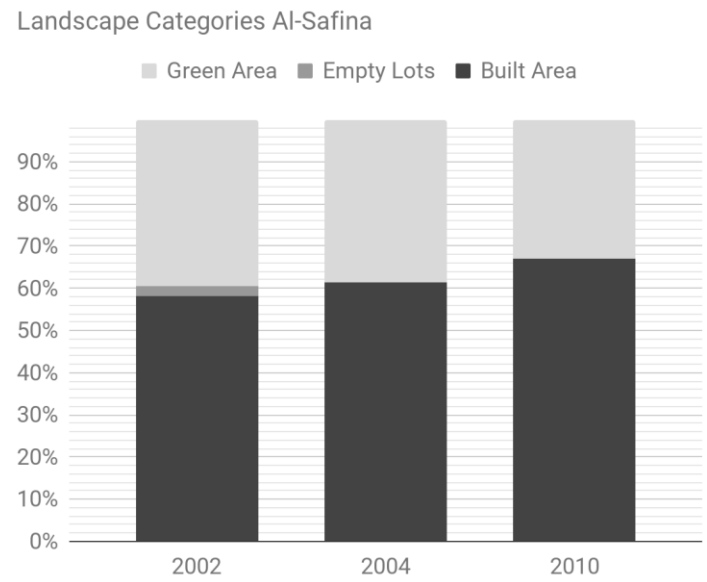


Figure 5.13 Changes in the land categories percentages during the years (2002, 2004, and 2010) in Al-Safina study site.

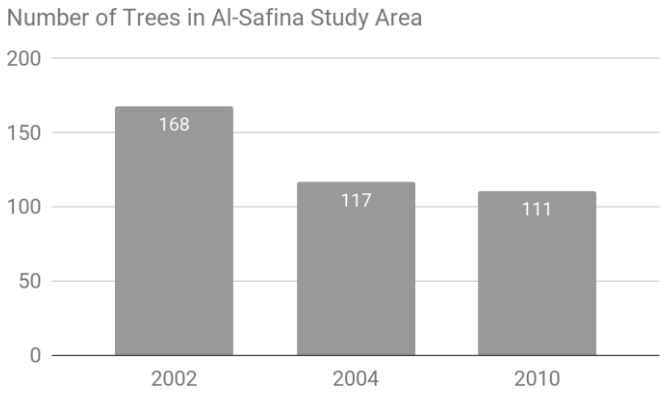


Figure 5.14 Number of trees changes during the years (2002, 2004, and 2010) in Al-Safina study site.

5.1.3 Al-Habibiya

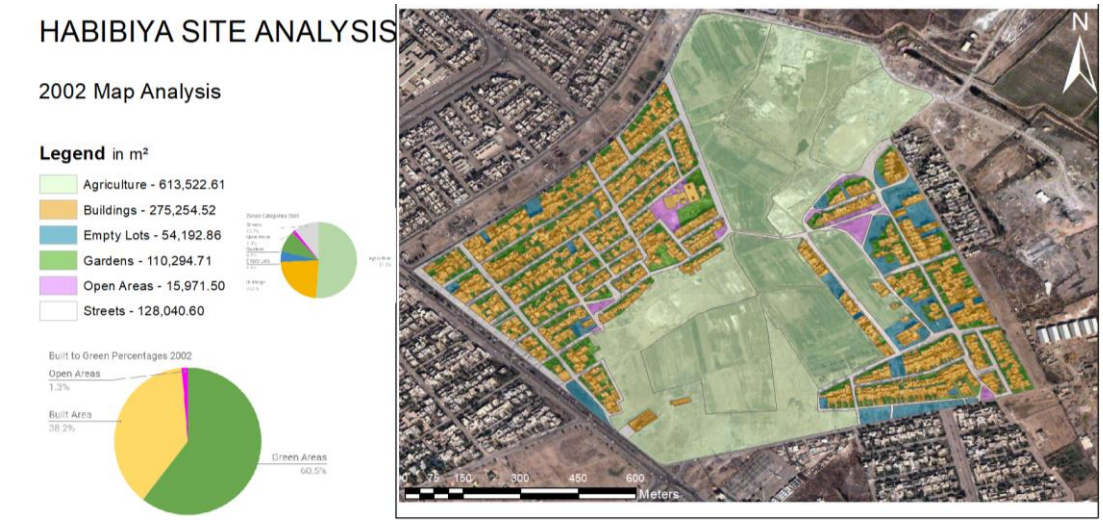


Figure 5.15 Map analysis of Al-Habibiya in the year 2002.

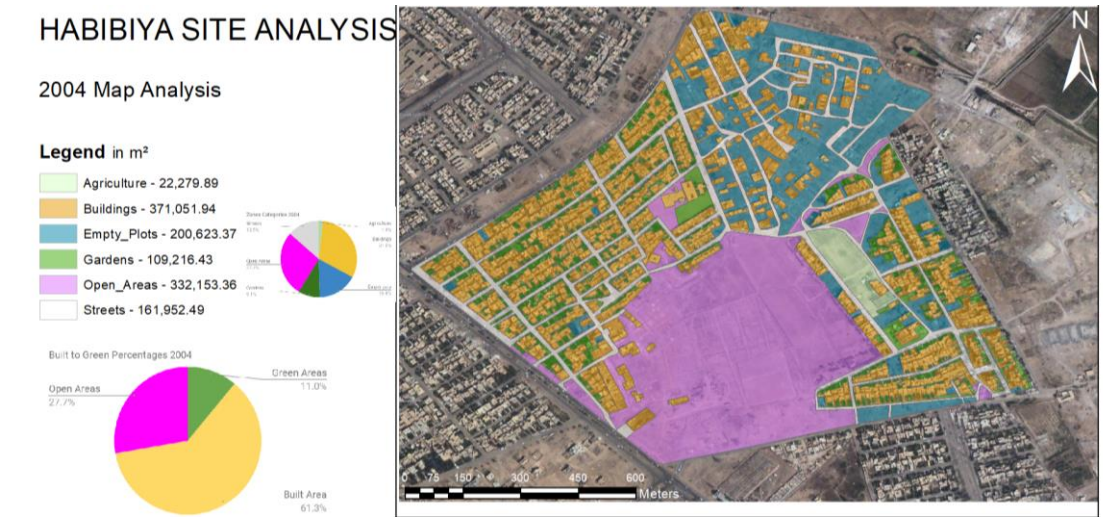


Figure 5.16 Map analysis of Al-Habibiya in the year 2004.

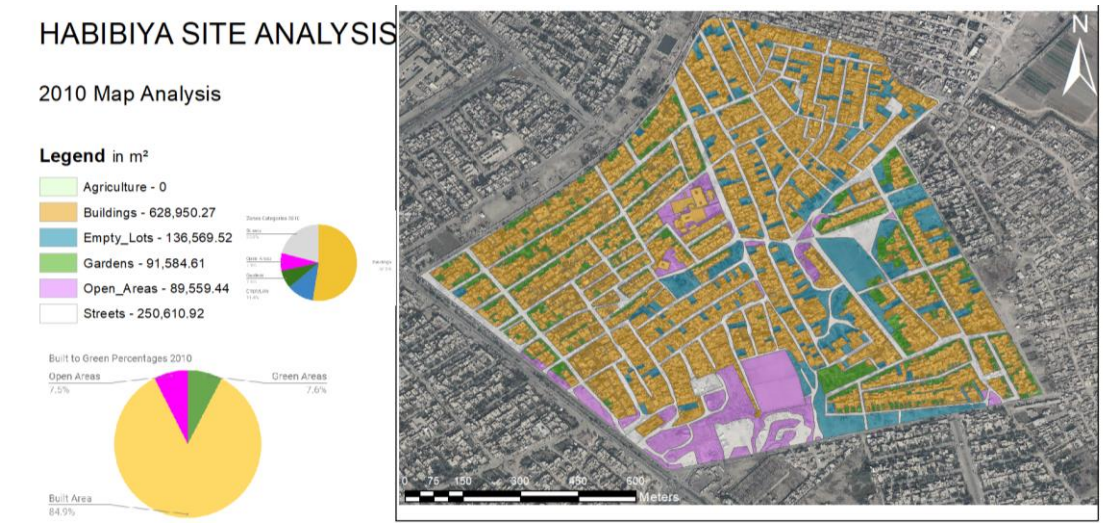


Figure 5.17 Map analysis of Al-Habibiya in the year 2010.

The (Figure 5.15), (Figure 5.16), (Figure 5.17) show that have occurred in Al-Habibiya study site, these are the results that were found in relation to this site:

1. The amount of green areas have decreased more than 87% throughout the specified time period. (Figure 5.18).

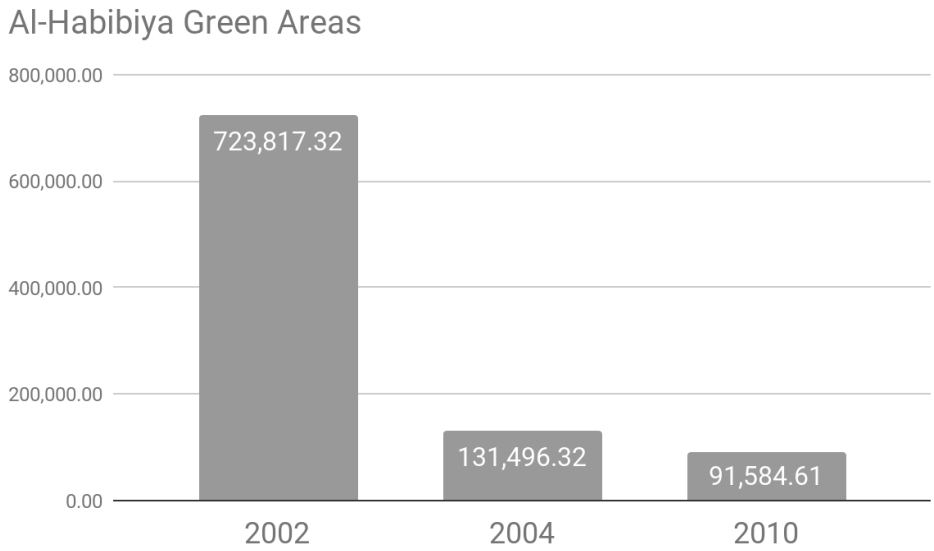


Figure 5.18 Green areas (including Agricultural land, open areas that are green, and private gardens) changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

2. The built areas have increased more than 133% during the specified time period. (Figure 5.19).

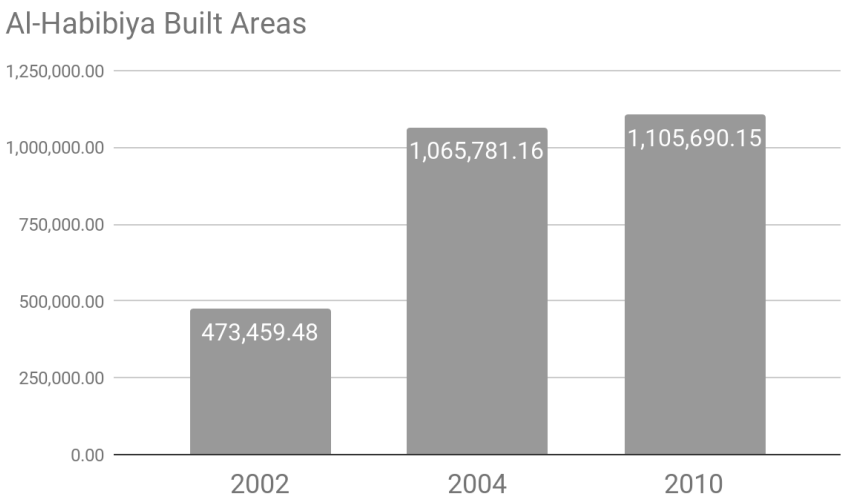


Figure 5.19 Built areas (including houses and streets) changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

3. Agricultural area disappeared through the specified time period. By 2010, there was no more agricultural area. (Figure 5.20).

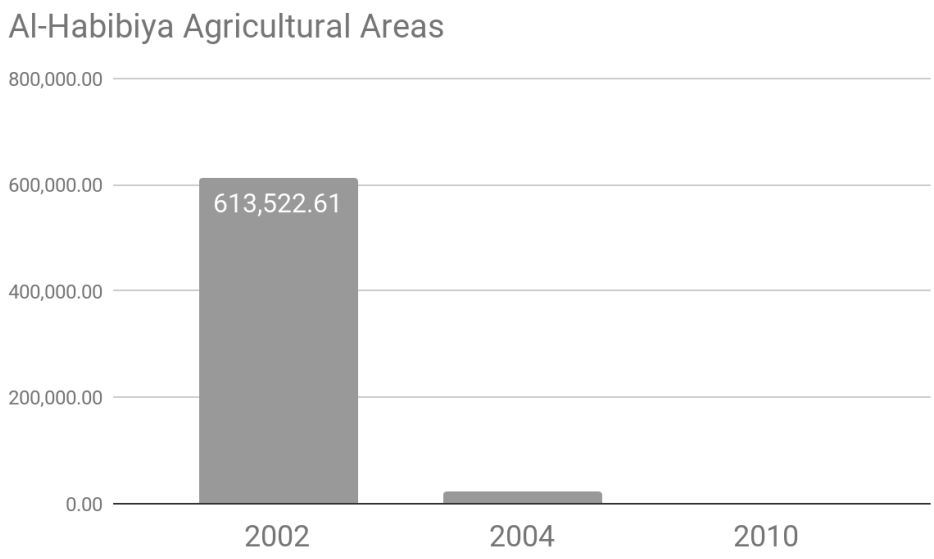


Figure 5.20 Agricultural areas changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

4. Private gardens areas have decreased almost 17% during the specified time period (Figure 5.21).

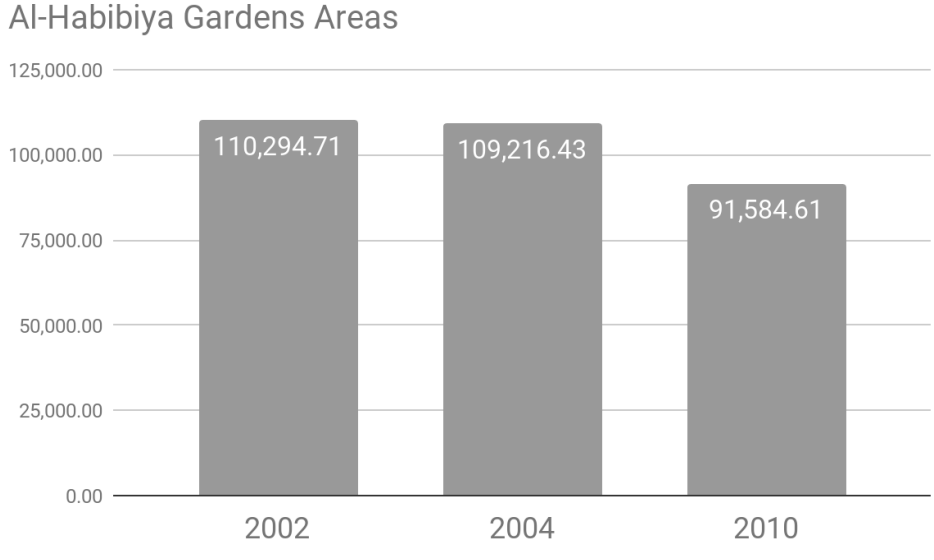


Figure 5.21 Gardens areas changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

5. Newer streets were built on the previous agricultural area. Overall streets areas increased 95%. (Figure 5.22).

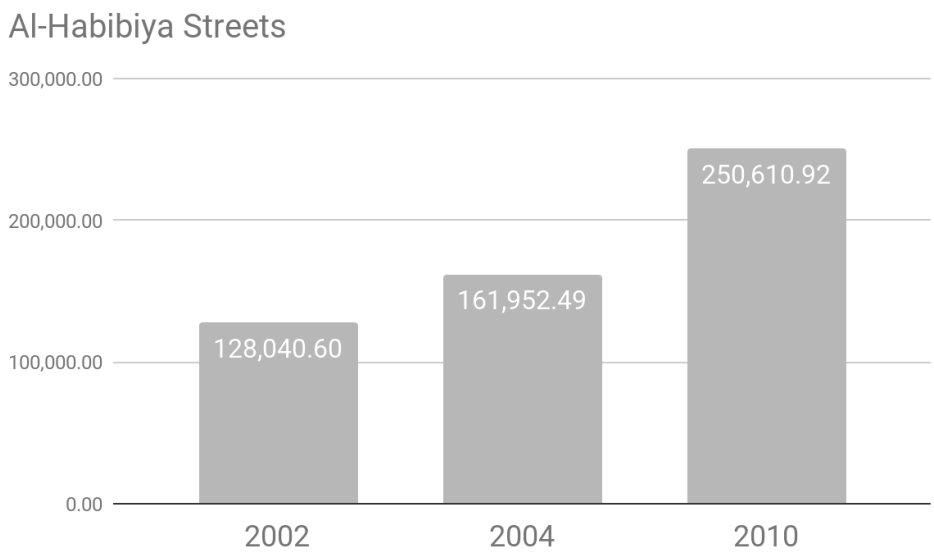


Figure 5.22 Streets areas changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

6. Built houses area have increased 128.5% during the specified time period (Figure 5.23).

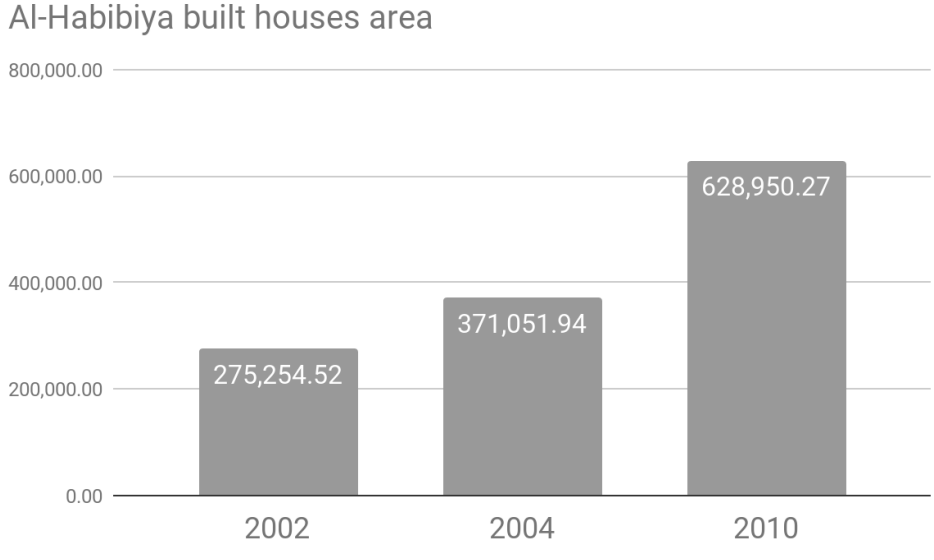


Figure 5.23 Built houses areas changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

7. Empty lots (unbuilt but specified for building areas) have increased more than 152% during the specified time period. (Figure 5.24).

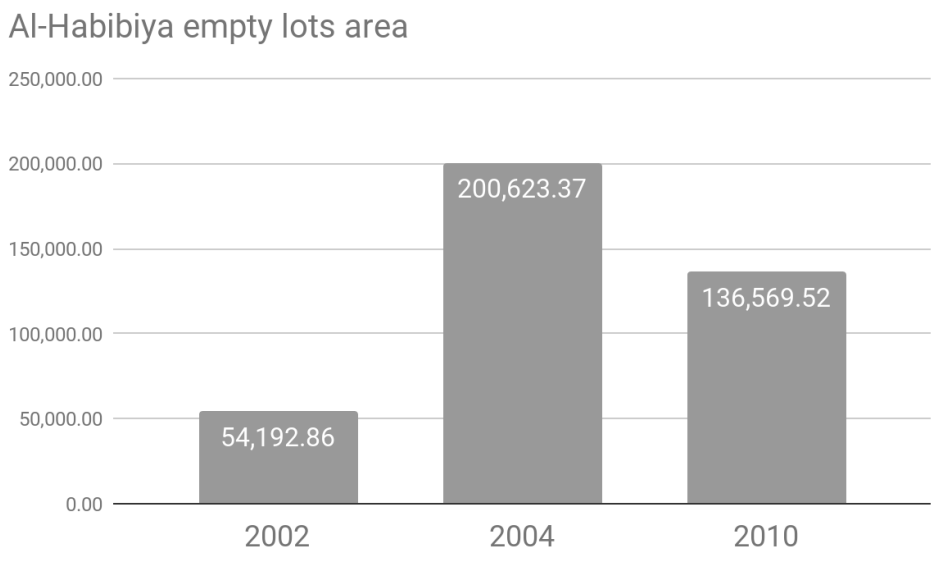


Figure 5.24 Empty lots areas changes during the years (2002, 2004, and 2010) in Al-Habibiya study site in m².

8. Streets were composing only 10.7% in 2002, the increased to around 20.9% in 2010.(Figure 5.25).
9. Open areas (which include non-developed areas that are not green or agriculture) used to compose 1.3% only in 2002, by 2010, they composed 7.5% of the total case study area. (Figure 5.25).
10. Gardens used to compose 9.2% in 2002. By 2010, they decreased to 7.6% of the total case study area. (Figure 5.25).
11. Buildings used to compose 23% in 2002, by 2010 the area increased to 52.5%, of the total case study area, more than double what it was. (Figure 5.25).
12. Agricultural areas used to make 51.2% in 2002 (Figure 5.25), (Figure 5.26).
13. Empty lots (developed areas that are intended to be built but are empty at the specified time of survey, and that are not green) used to compose 4.5% of the total case study area in 2002, by 2010 they composed 11.4% of the study area. (Figure 5.25).

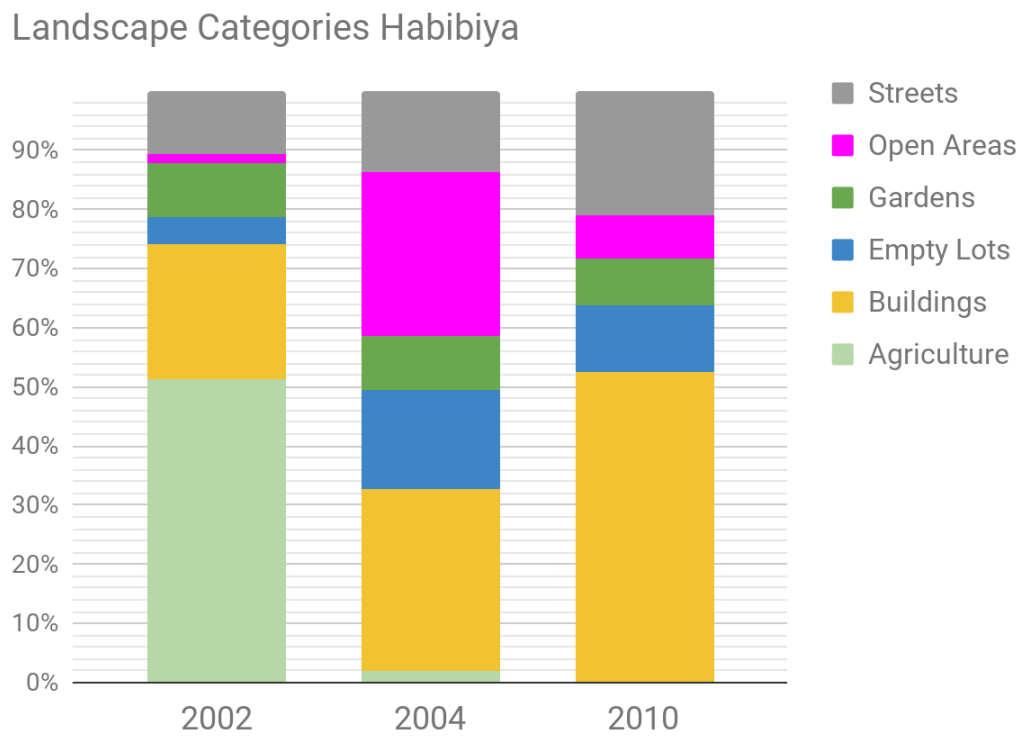


Figure 5.25. Changes in the land categories percentages during the years (2002, 2004, and 2010) in Al-Habibiya study site.

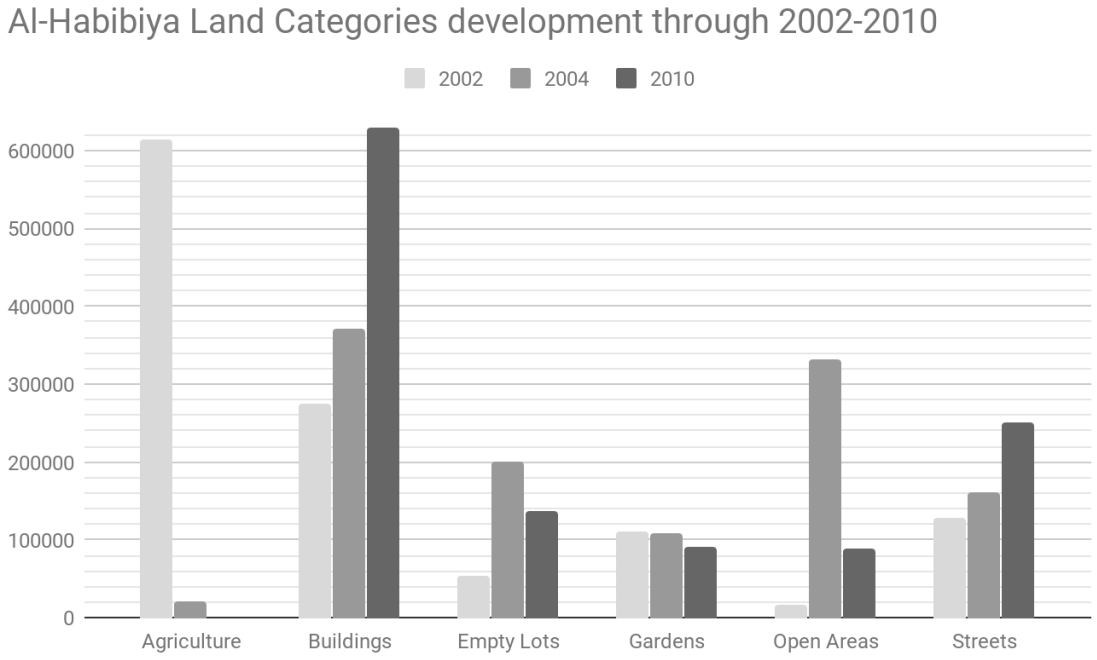


Figure 5.26 Changes in the land categories individually during the years (2002, 2004, and 2010) in Al-Habibiya study site.

5.1.4 Al-Sinak

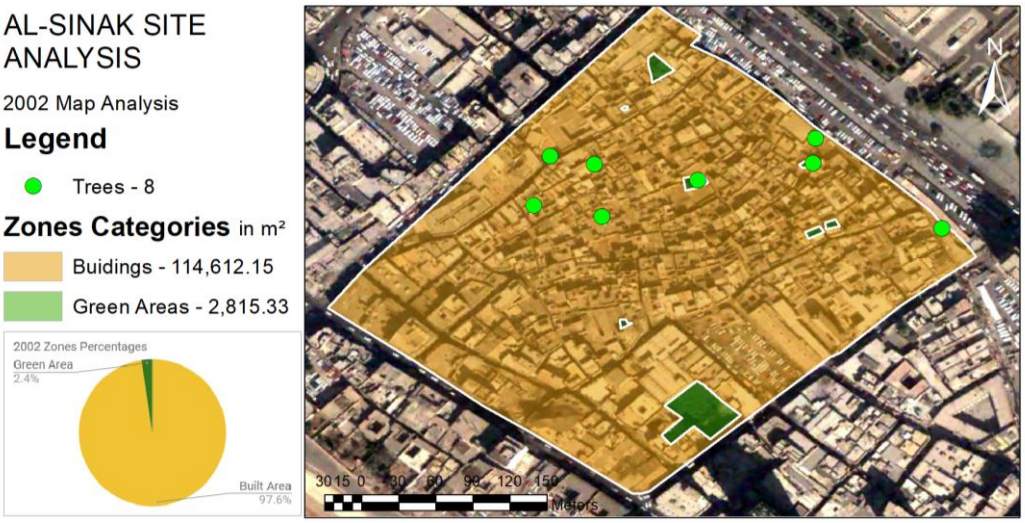


Figure 5.27 Map analysis of Al-Sinak in the year 2002.

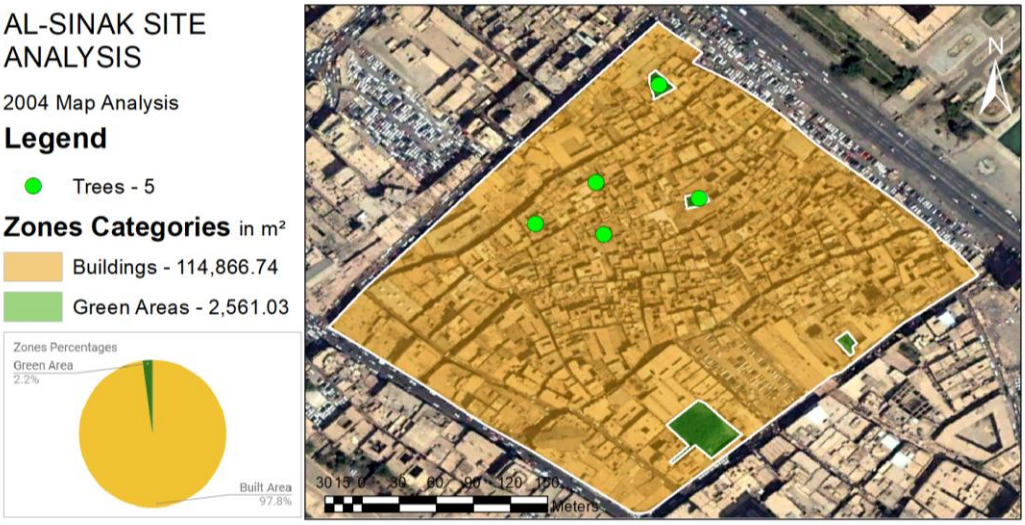


Figure 5.28 Map analysis of Al-Sinak in the year 2004.

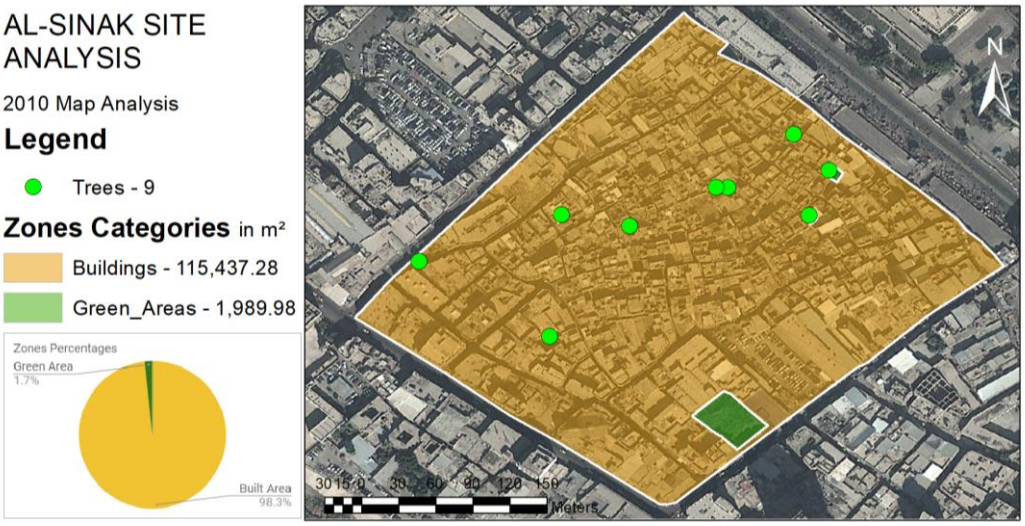


Figure 5.29 Map analysis of Al-Sinak in the year 2010.

The (Figure 5.17), (Figure 5.28), (Figure 5.29) show that have occurred in Al-Sinak study site, these are the results that were found in relation to this site:

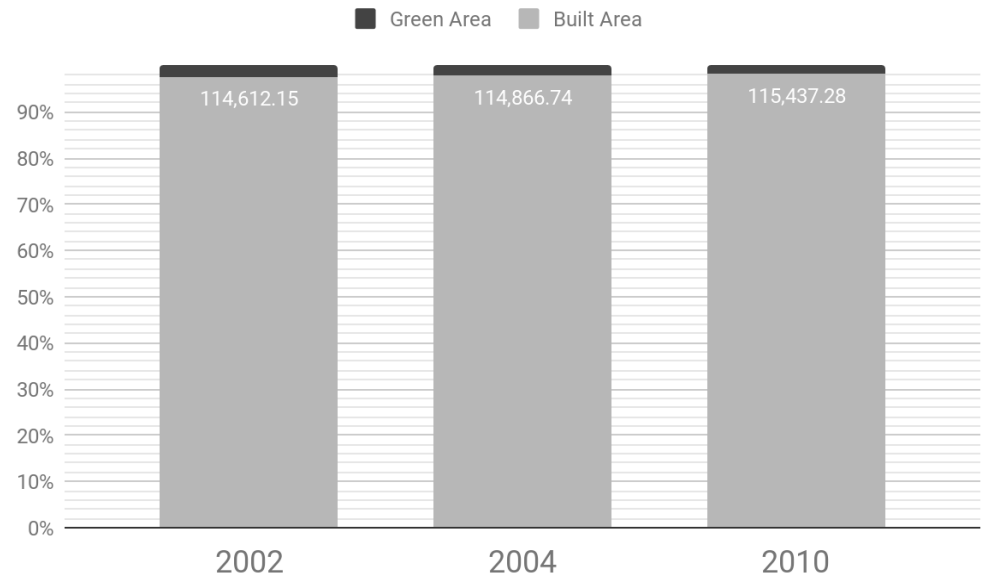


Figure 5.30 Changes in the land categories percentages during the years (2002, 2004, and 2010) in Al-Sinak study site.

1. Even though the green areas composed only 2.4% of the urban cover of Al-Sinak site in 2002 (Figure 5.30) it has decreased more than 29% during the specified time period (Figure 5.31) to become 1.69% of the overall land cover of the case study site in 2010.

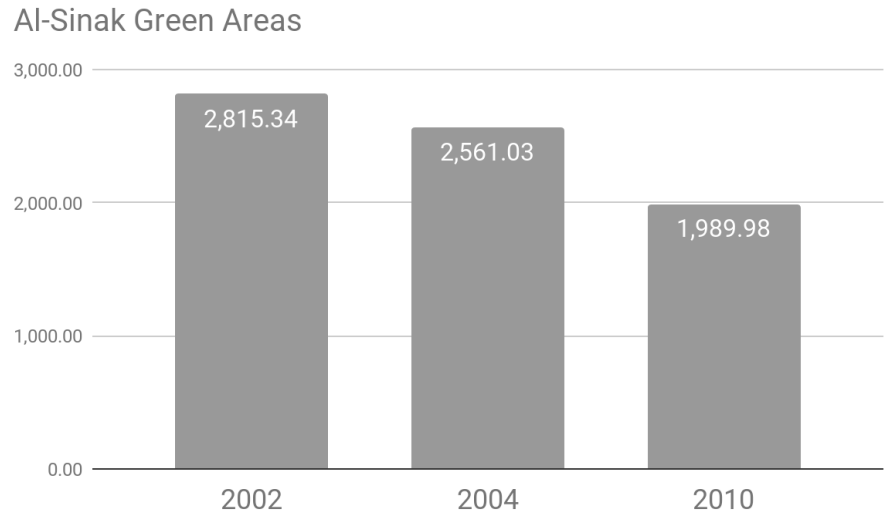


Figure 5.31 Green areas changes during the years (2002, 2004, and 2010) in Al-Sinak study site in m².

2. Built urban cover have increased 0.72% from the overall site cover during the specified period of time (Figure 5.32), it increased from 97.6% in 2002, to 98.3% in 2010. (Figure 5.30).

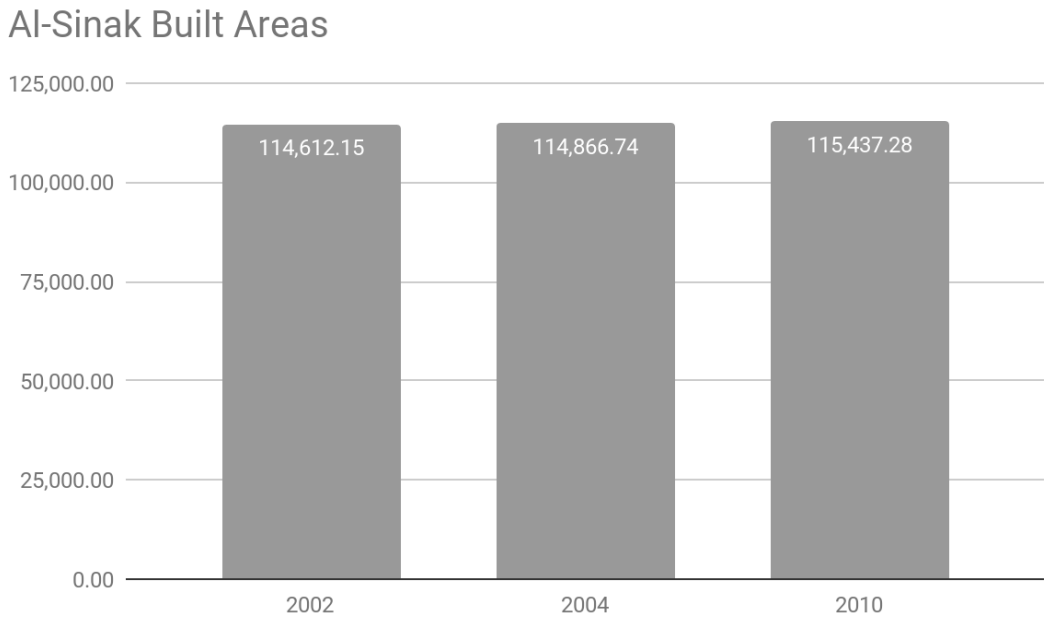


Figure 5.32 Built areas changes during the years (2002, 2004, and 2010) in Al-Sinak study site in m².

3. Even though the amount of trees in this site is very small, the amount of trees have increased from 8 trees in 2002, to 9 trees in 2010. An increase of 12.5% through the specified period (Figure 5.33).

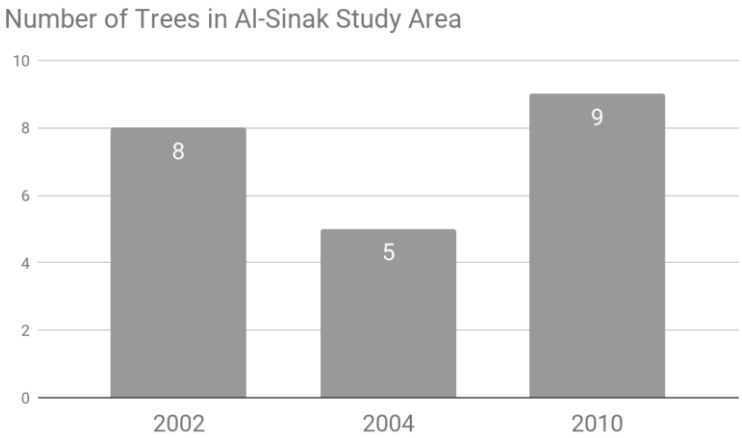


Figure 5.33 Number of trees changes during the years (2002, 2004, and 2010) in Al-Sinak study site.

5.2 Questionnaire results.

The following results were found from the questionnaire that was published.

5.2.1 General results

1. The majority of responders (71.6%) believe that Baghdad used to be green and now is a desert city. (Figure 5.34).

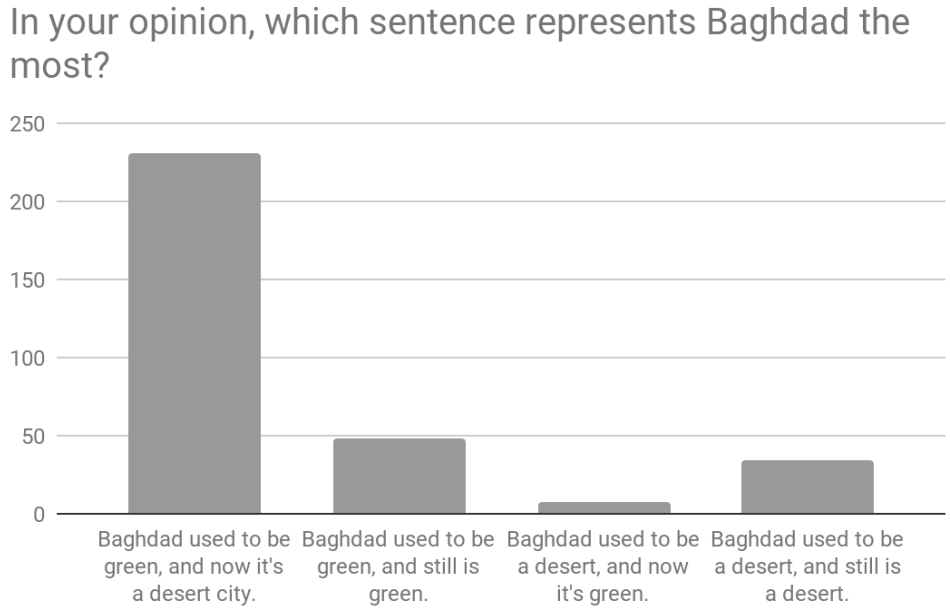


Figure 5.34 Questionnaire results for the question: what's the sentence that represents Baghdad the most?

2. 59.8% of the people do not visit a park even once a month. And 32.9% visit once to four times a month only. (Figure 5.35).

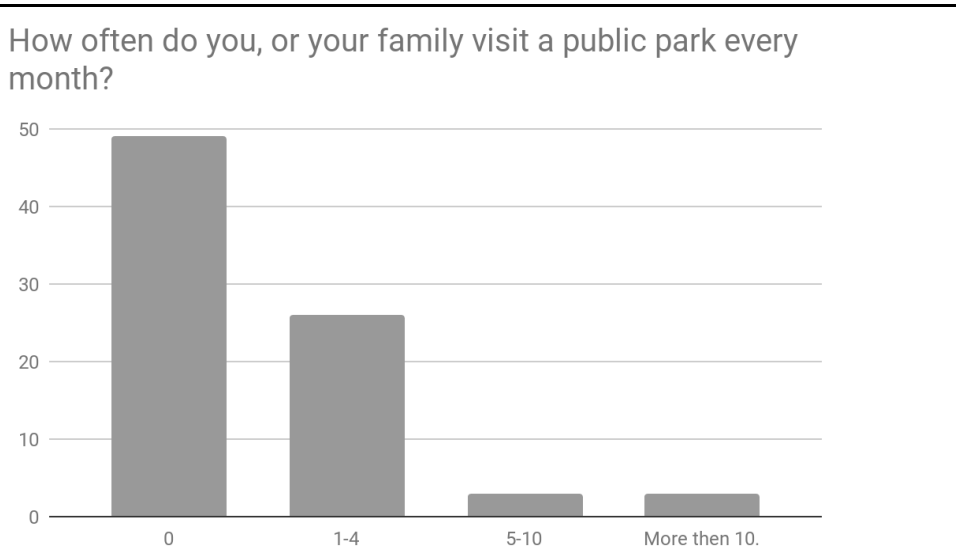


Figure 5.35 Questionnaire results for the question: How often do you, or your family visit a park every month? (approximately)

3. 29.9% of the people do not have a public park in their neighbourhoods, and 31.5% live more than a kilometre away from the closest public park. (Figure 5.36).
4. Only 23.8% live within 500 meters away from a public park. (Figure 5.36).

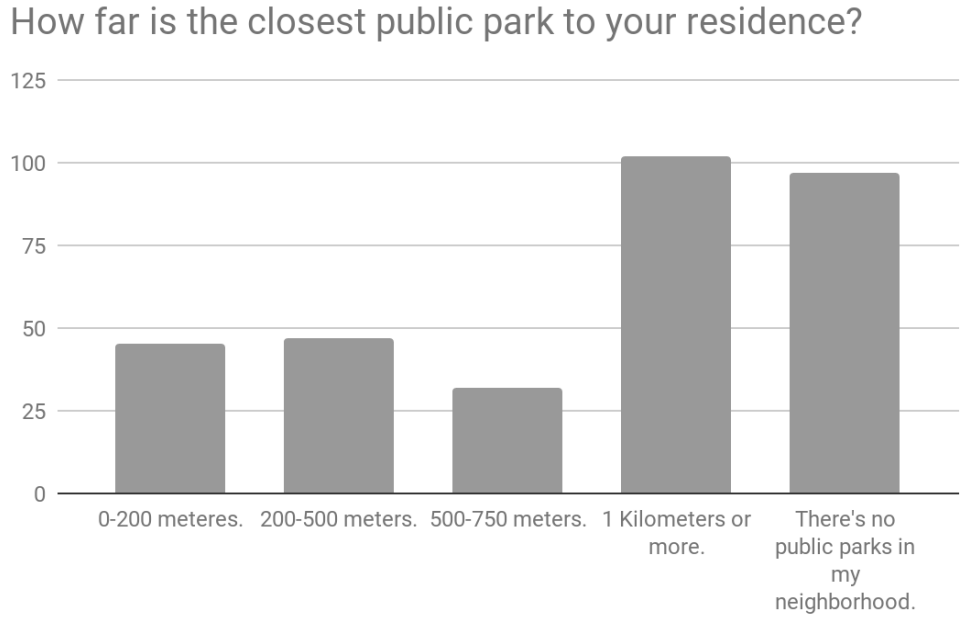


Figure 5.36 Questionnaire results for the question: how far do people live from public parks? (approximately)

5. Out of the 70.1% of the respondents who have a public park in their neighbourhood, 70.8% can access it for free, 19.9% said that they have to pay a fee to access these parks, and 9.3% don't know. (Figure 5.37).

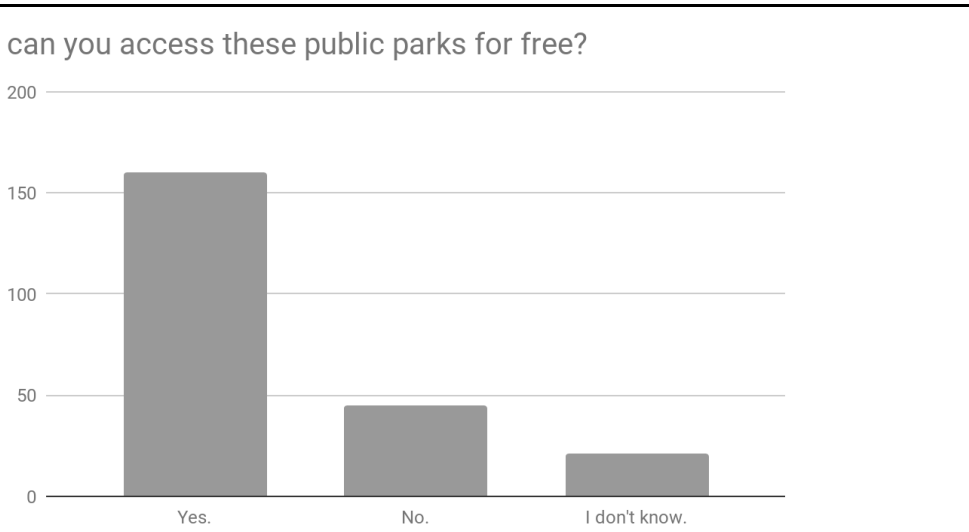


Figure 5.37 Questionnaire results for the question: do they have access to these parks for free? (for those who have public parks close to their homes.)

6. 45.6% of the respondents live in a house with a private garden, 9% live in house with shared garden, and 4.3% live in house with a private farm or forest. (Figure 5.38).
7. 35.3% live in a house that doesn't have a garden, 4.3% live in an apartment in a building with its own private garden (shared with other residents), and 1.5% live in an apartment that doesn't have a garden. (Figure 5.38).

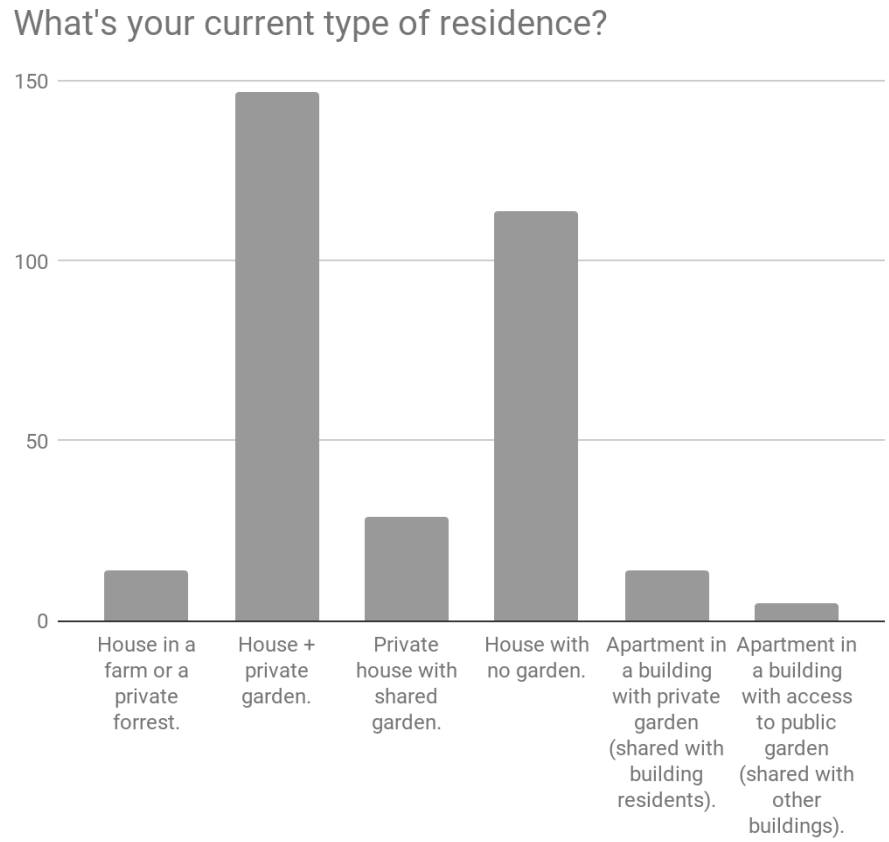


Figure 5.38 Questionnaire results for the question: type of current residence

8. Out of the respondents who are living in house with no garden, or an apartment building that has its own private garden, or a an apartment building that doesn't have access to a private garden (Figure 5.38). 74.8% used to live in a house with a private garden, and 17.9% live in a house with a shared garden, and 6.5% live in house with a private farm or forest. (Figure 5.39).

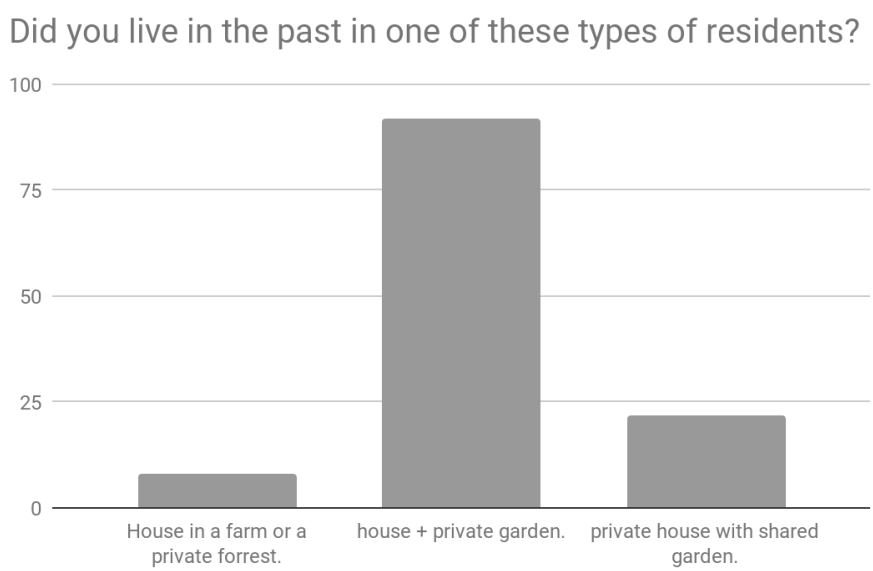


Figure 5.39 Questionnaire results for the question: type of previous residence? (In case the response was that, they do not have a garden in their home).

9. 5.6% of the respondents live in neighbourhoods with houses that do not have gardens. (Figure 5.40).
10. 40.9% live in neighbourhoods that 1-25% of the houses there have gardens, and 27.2% of the respondents live in neighbourhoods that 26-50% of the houses have private gardens. (Figure 5.40).
11. 16.4% live in neighbourhoods that have 51-75% of the houses have gardens, and 9.9% live in neighbourhoods that have 76-100%. (Figure 5.40).

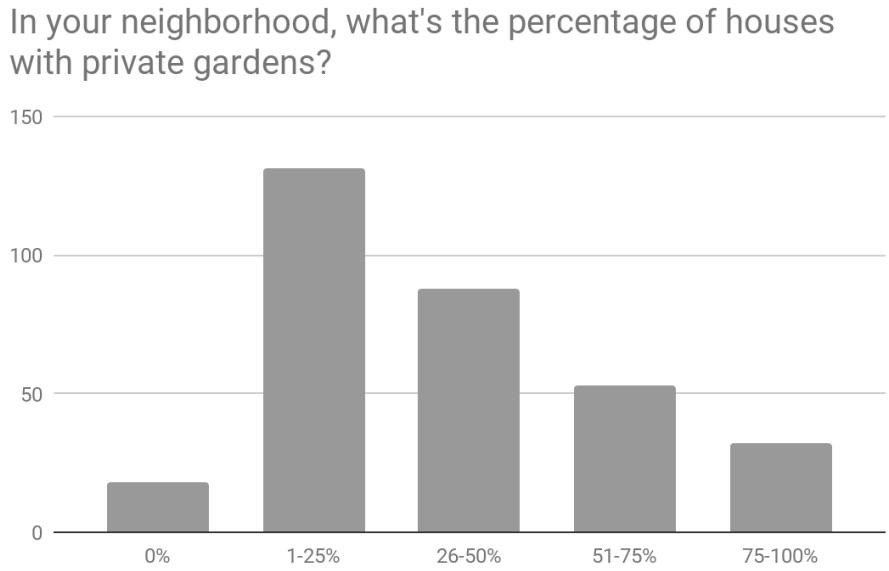


Figure 5.40 Questionnaire results for the question: the current percentage of houses with private gardens in the respondents neighbourhood? (Approximation).

12. 3.4% of the respondents said that 0% of the houses in their neighbourhood have lost their garden due to house extension, or building a new house in the gardens. (Figure 5.41).
13. 17.6% of the respondents said that 1-25% of the houses in their neighbourhood have lost their garden due to house extension, or building a new house in the gardens. (Figure 5.41).
14. 21.4% of the respondents said that 26-50% of the houses in their neighbourhood have lost their garden due to house extension, or building a new house in the gardens. (Figure 5.41).
15. Almost a third of the respondents (33.1%) said that 51-75% of the houses in their neighbourhood have lost their garden due to house extension, or building a new house in the gardens. (Figure 5.41).
16. Almost a quarter of the respondents (24.5%) said that 75-100% of the houses in their neighbourhood have lost their garden due to house extension, or building a new house in the gardens. (Figure 5.41).

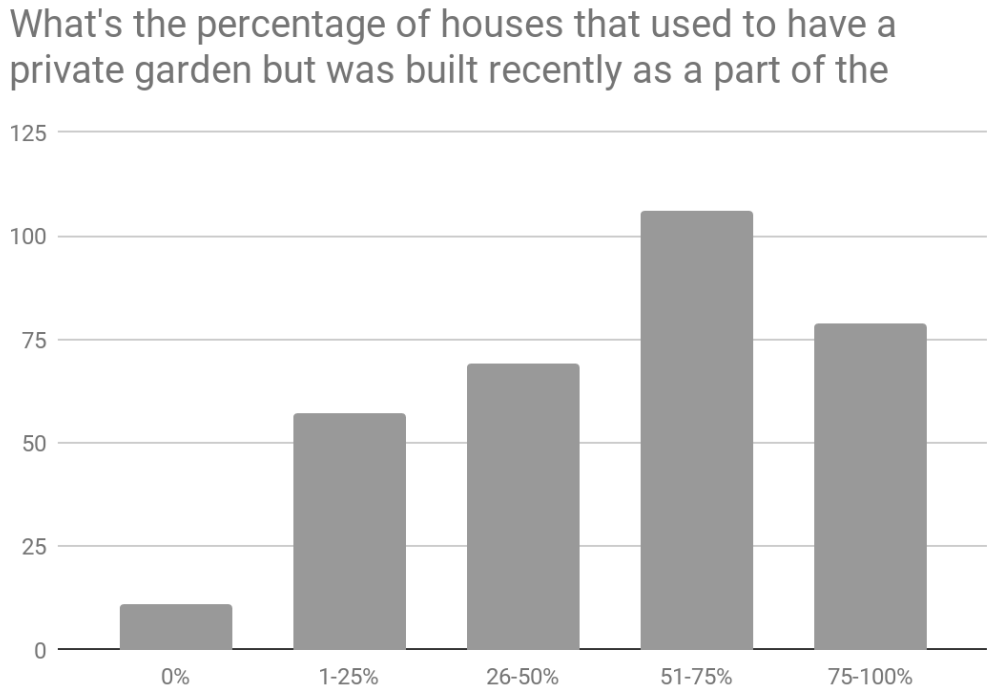


Figure 5.41 Questionnaire results for the question: percentage of houses that used to have private gardens in the respondents neighbourhood? (Approximation).

17. The majority of the respondents (83.3%) completely agree that there is a relation between the presence of trees and thermal comfort at home. (Figure 5.42).

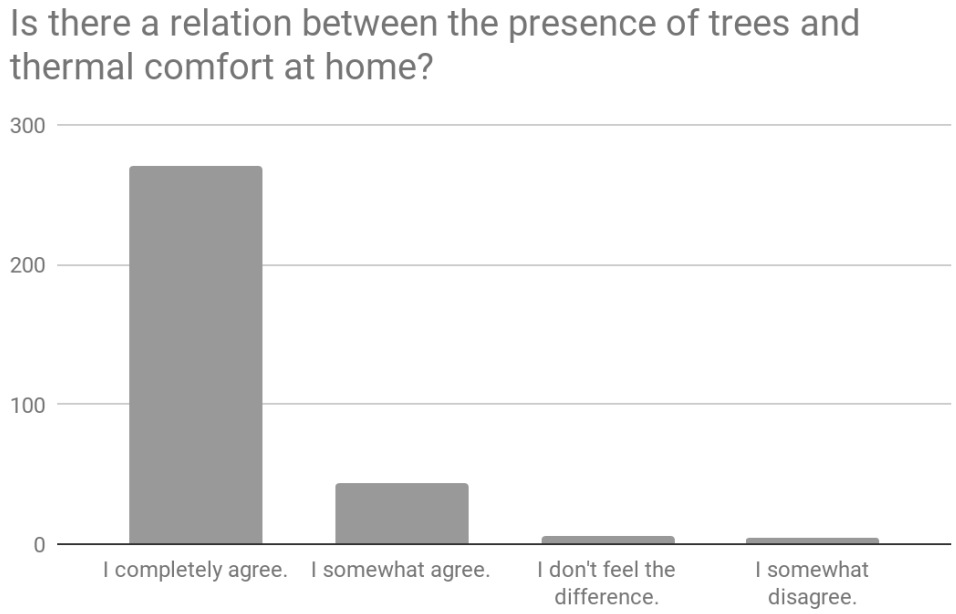


Figure 5.42 Questionnaire results for the question: is there a relation between the presence of trees and thermal comfort at home?

18. The majority of the respondents (87%) completely agree that there is a relation between the presence of trees and thermal comfort outside the home. (Figure 5.43).

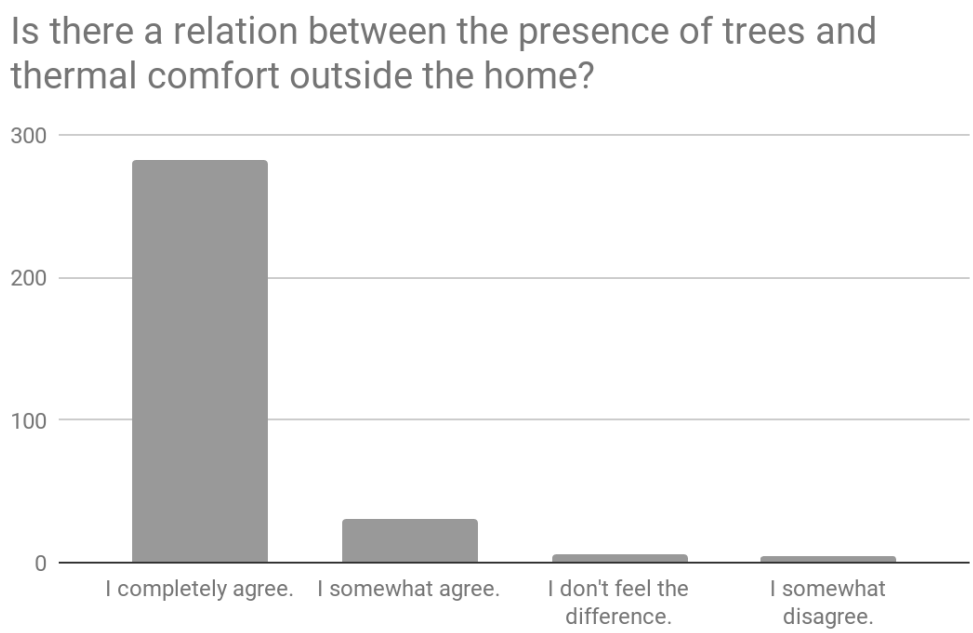


Figure 5.43 Questionnaire results for the question: is there a relation between the presence of trees and thermal comfort at outside the home (in the streets)?

19. The majority of the respondents (90.4%) completely agree that there is a relation between the presence of trees and physiological comfort at home. (Figure 5.44).

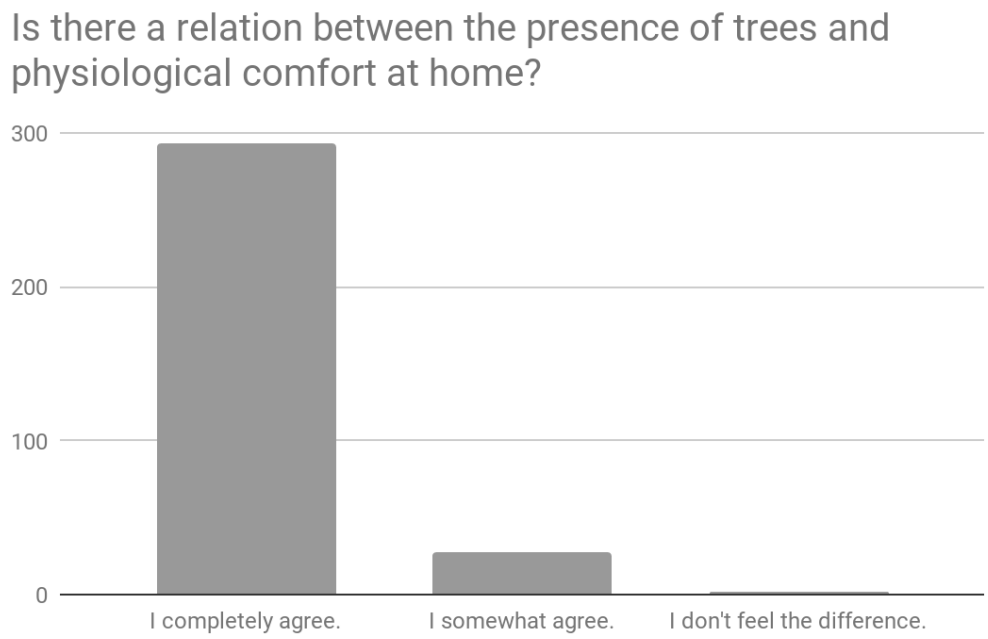


Figure 5.44 Questionnaire results for the question: is there a relation between the presence of trees and physiological comfort at home?

20. The majority of the respondents (92.9%) completely agree that there is a relation between the presence of trees and physiological comfort outside the home. (Figure 5.45).

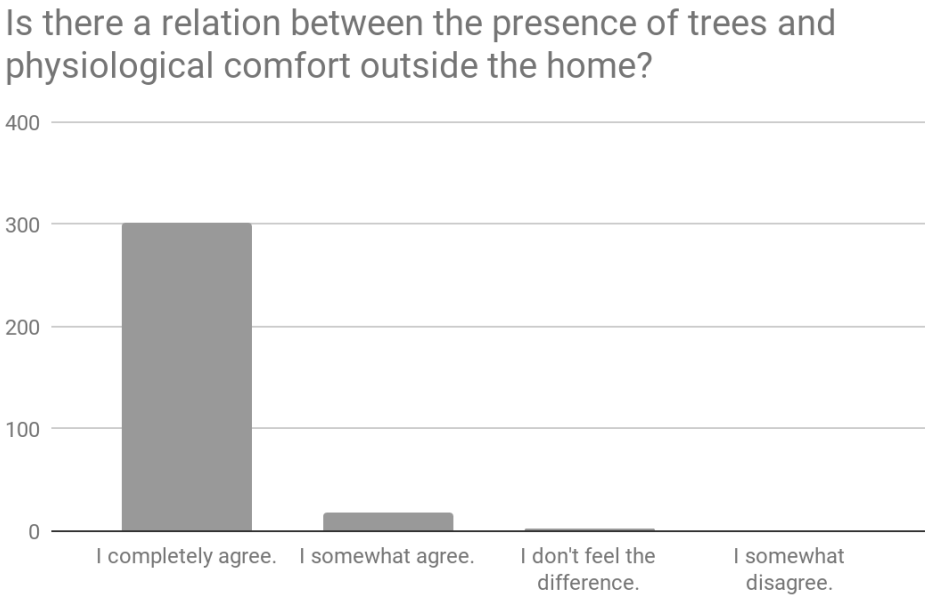


Figure 5.45 Questionnaire results for the question: is there a relation between the presence of trees and physiological comfort at outside the home (in the streets)?

21. The majority of respondents (68.5%) say that there is a high decrease in the amount of trees and green areas through the period of 2000-2018. (Figure 5.46).

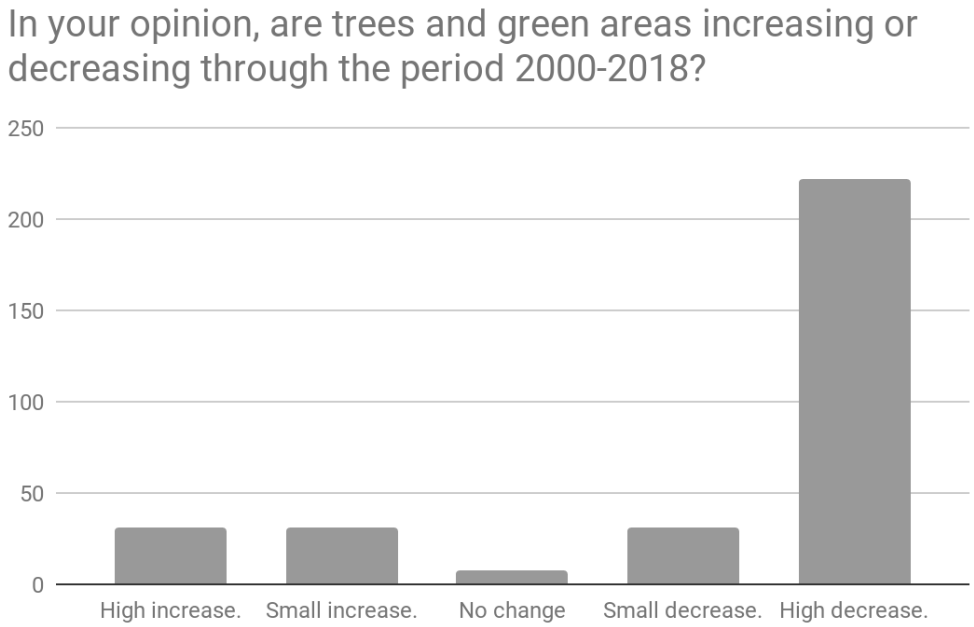


Figure 5.46 Questionnaire results for the question: Whether trees have increased or decreased through the period 2000-2018?

22. 58% of the respondents feel that the life quality have highly deteriorated in relation to the current quality of trees and green areas. (Figure 5.47).

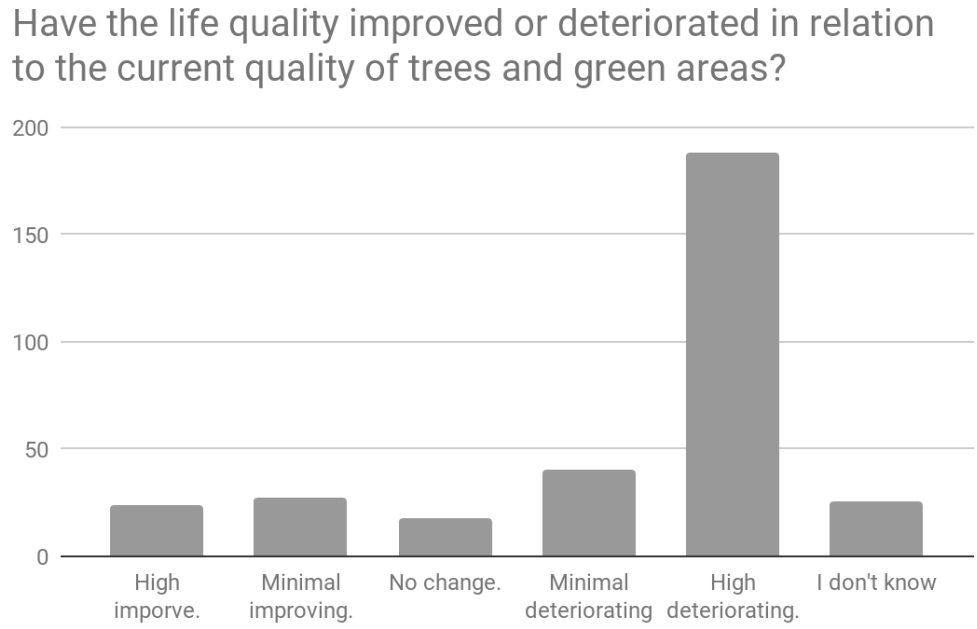


Figure 5.47 Questionnaire results for the question: Whether the life quality have improved or deteriorated in relation to the current quality of trees and green areas?

23. At home, 39.5% say that ornamental trees, plants, and flowers are the most important at home, 33.6% say that its fruit trees, and 26.9% chose Trees that functions to improve the atmosphere, for shading and cleaning the air, but have no fruits or ornamental value. (Figure 5.48).

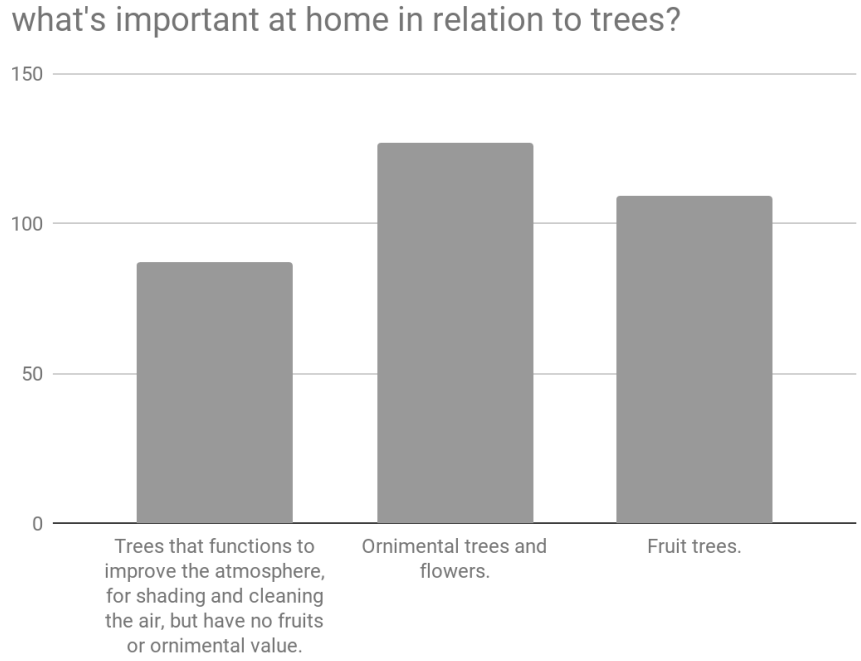


Figure 5.48 Questionnaire results for the question: what's important at home in relation to trees and plants.

24. Outside the home; 15.4% say that ornamental trees, plants, and flowers are the most important at home, 17% say that it's fruit trees, and 67.6% chose Trees that functions to improve the atmosphere, for shading and cleaning the air, but have no fruits or ornamental value. (Figure 5.49).

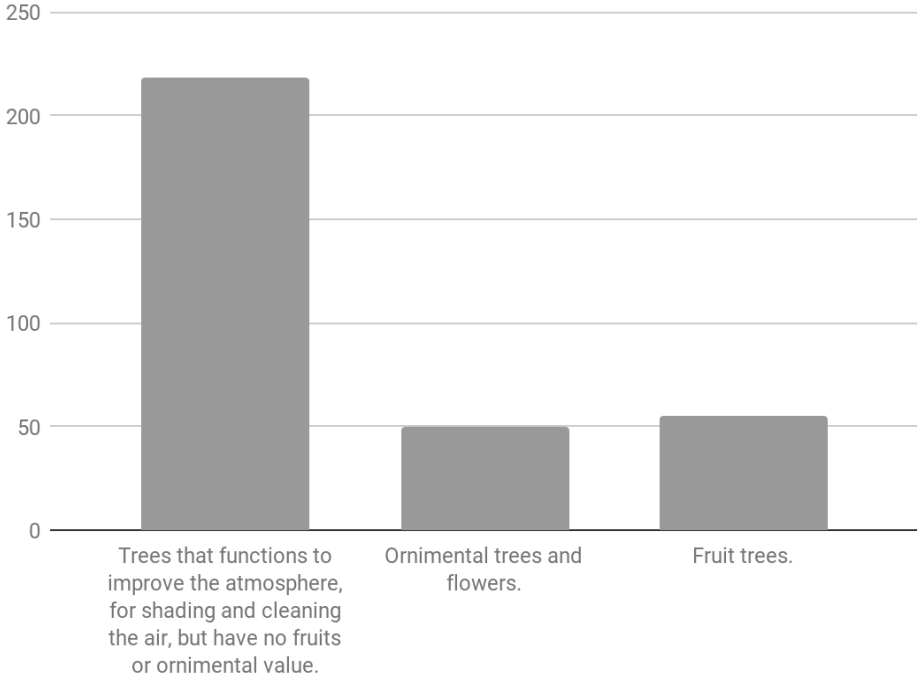


Figure 5.49 Questionnaire results for the question: what's important at outside the home (in the streets) in relation to trees and plants?

25. More than 77% of the people said they are willing to participate in campaign to plant and maintain trees, plants, and green areas. (Figure 5.50).

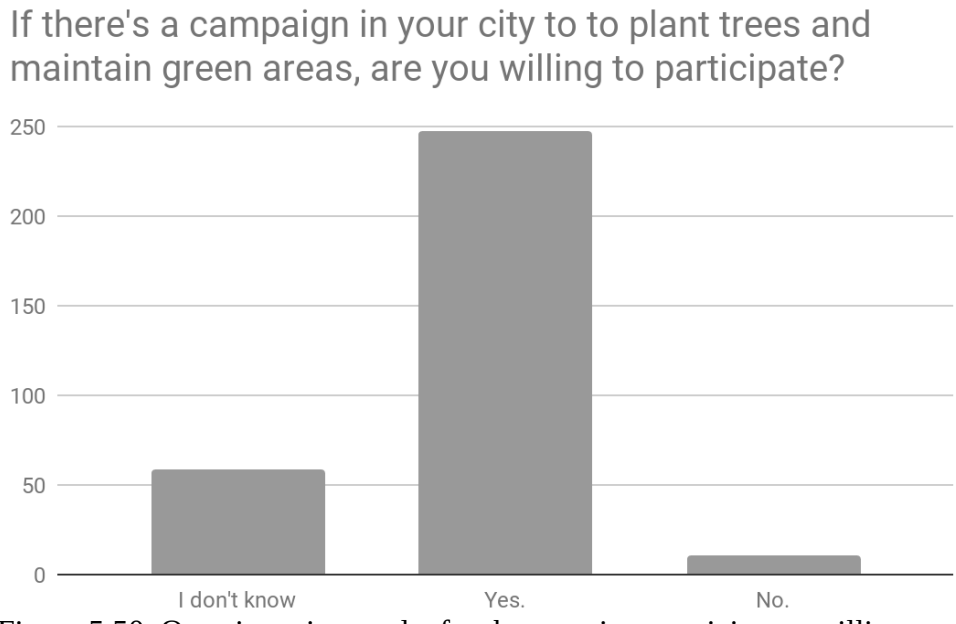


Figure 5.50 Questionnaire results for the question: participants willingness to participate in campaigns for planting and maintaining green areas.

26. Out of those who are willing to participate in the planting campaigns, 25.6% are willing to participate monthly, 19.8% weekly, 38.1% depending on their free time. (Figure 5.51).

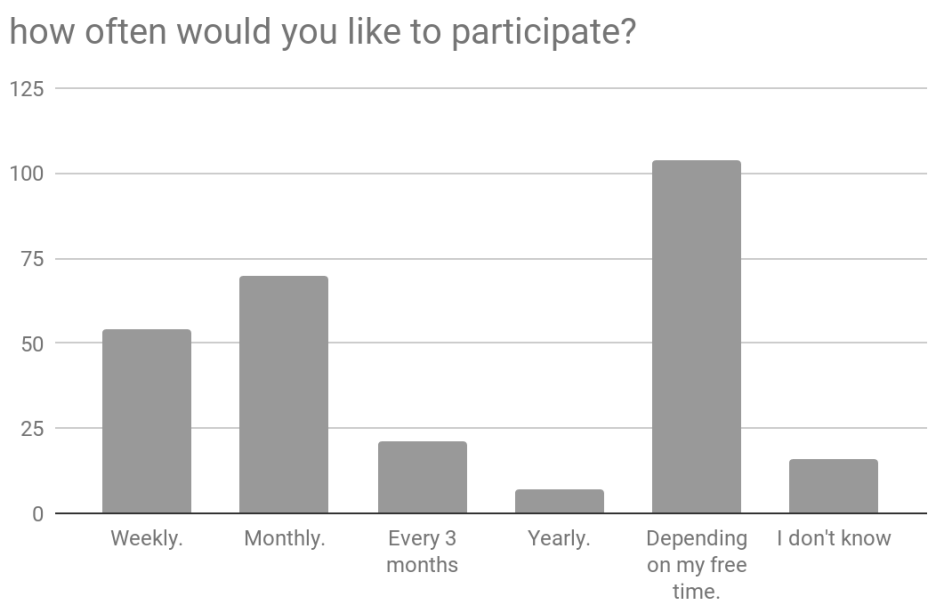


Figure 5.51 Questionnaire results for the question: how often do participants willing to participate in campaigns? (For participants who are willing to participate in campaigns for planting and maintaining green areas).

5.2.2 Results based on the gender of the questionnaire respondents

27. Women are slightly less likely to "completely agree that there is a direct relation between the presence of trees and thermal comfort at home" (Figure 5.52).
28. Women are slightly less likely to "completely agree that there is a direct relation between the presence of trees, and thermal comfort outside the home (streets)" (Figure 5.53).
29. Men are 11.7% more to say that the amount of trees have decreased through the period 2000-2018 (Figure 5.54).
30. Women are slightly more likely to say that the life quality have improved in regards to the current green areas situation (Figure 5.55).
31. Woman like ornamental trees, plants and flowers slightly more than men at the home.(Figure 5.56).
32. Men are prefer functional air cleaning/shading trees slightly more than women at home. (Figure 5.56).

33. Both men and women prefer ornamental plants and trees more than fruit and functional trees (Figure 5.56).
34. Both men and women prefer ornamental trees the most, followed by fruit trees, and lastly functional trees (Figure 5.56).
35. Both women and men prefer functional trees outside the home the most, although, women prefer them slightly more than men (Figure 5.57).

5.2.3 Results based on the age groups of the questionnaire respondents

36. People who are 18-45 years of age, tend to say that Baghdad used to be green and now is a desert more than other age groups, followed by people older than 45 years old, and you teens tend to say that "Baghdad used to be green, and still is green" (Figure 5.58).
37. People aged 18-30 years, say that they visit public parks more often than other age groups, followed by 30-45 years old age group (Figure 5.59).
38. At home: people younger than 18 and people older than 45, say that they prefer fruit trees more than the other age groups, people younger than 18 prefer functional trees the most in regards to other age groups, and people aged 30-45 years say that they prefer ornamental trees the most in regards to other tree types and other age groups (Figure 5.60).
39. Outside the home (streets): people older than 18 years say that they prefer functional trees overwhelmingly, people younger than 18 like fruit trees and functional trees almost equally, but much more than ornamental trees (Figure 5.61).
40. Younger people (12-30) tend to say that they see an increase in the number of trees and amount of green areas more than older respondents do, however they still all overwhelmingly say that the changes have been in the decline (Figure 5.62).
41. People younger than 18 say that the life quality has deteriorated in regards to the current situation of trees and green areas (Figure 5.63).
42. When splitting the two genders into two groups, and looking at the data of each gender group of different age groups, we can see similar results in the trends mention in results (29 and 40), and that on average within the same age group, men tend to see the decrease in the number of trees and amount of green areas (Figure 5.64) more than women (Figure 6.65).

Table 1 Spatial analysis based on the gender of the questionnaire respondents.

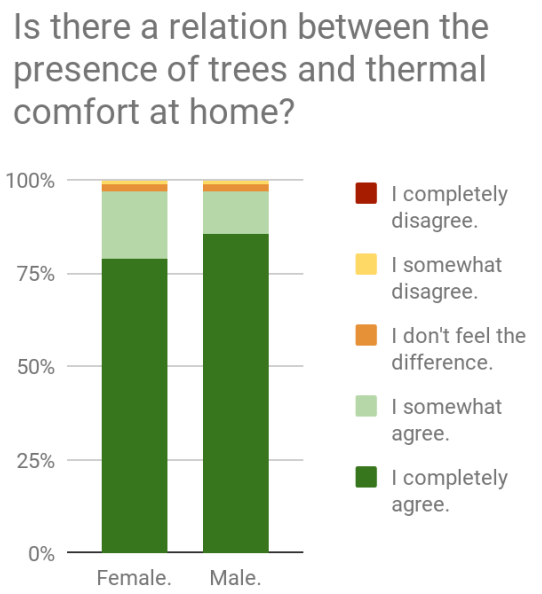


Figure 5.52 Different genders opinion in regards to the relation between the presence of trees and thermal comfort at home question.

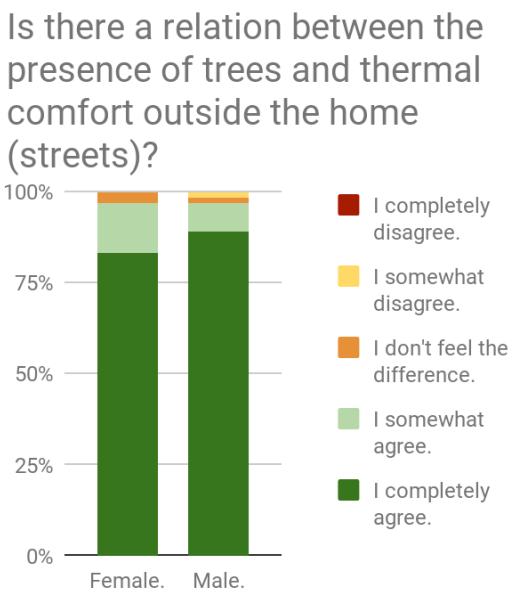


Figure 5.53 Different genders opinion in regards to the relation between the presence of trees and thermal comfort outside the home (streets) question.

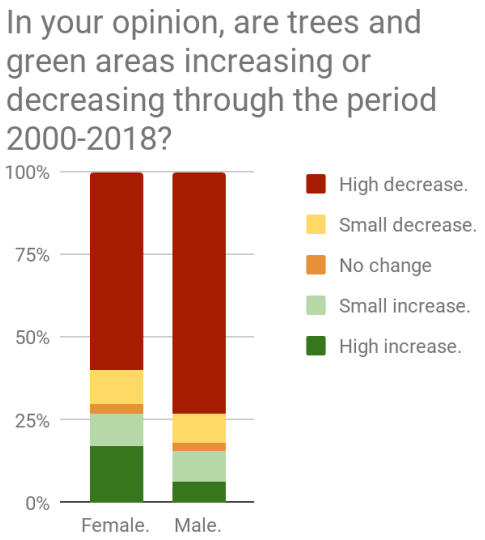


Figure 5.54 Different genders perception in regards to the number of trees and amount of green areas change during 2000-2018.

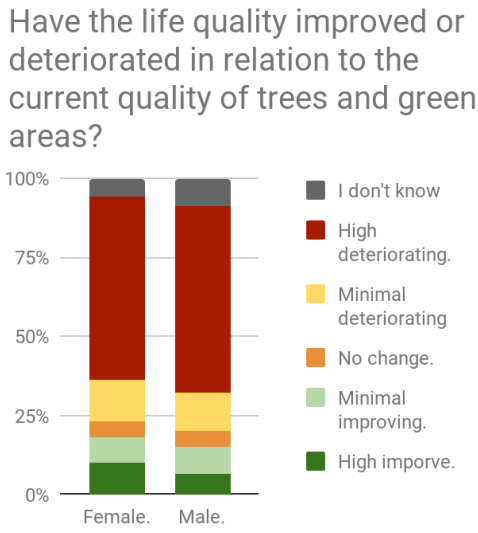


Figure 5.55 Different genders perception in regards to the life quality in regards to the current quality of trees and green areas of trees in recent years

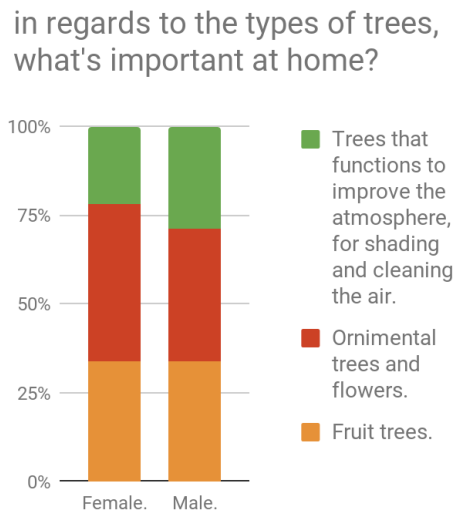


Figure 5.56 Different genders preferences in regards to the type of trees at home.

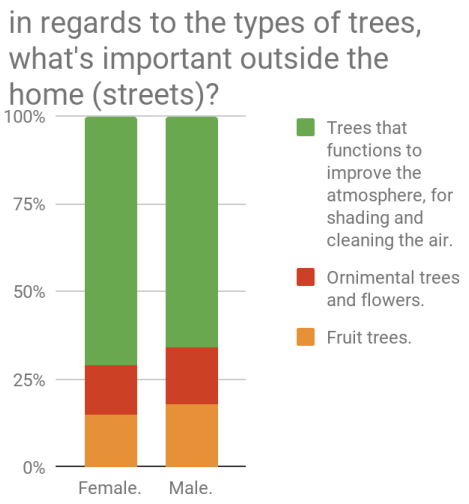


Figure 5.57 Different genders preferences in regards to the type of trees outside the home (streets).

Table 2 Spatial analysis based on the age group of the questionnaire respondents.

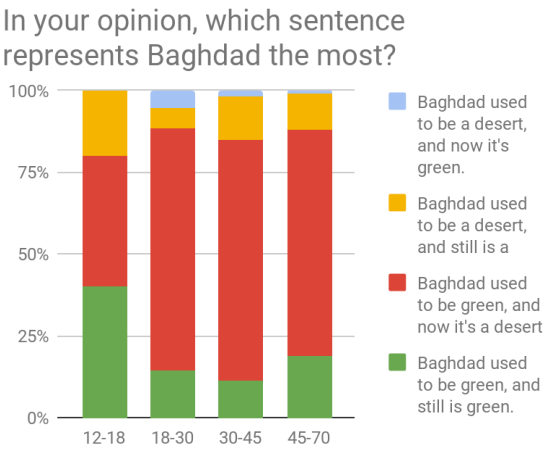


Figure 5.58 Different ages perception of Baghdad.

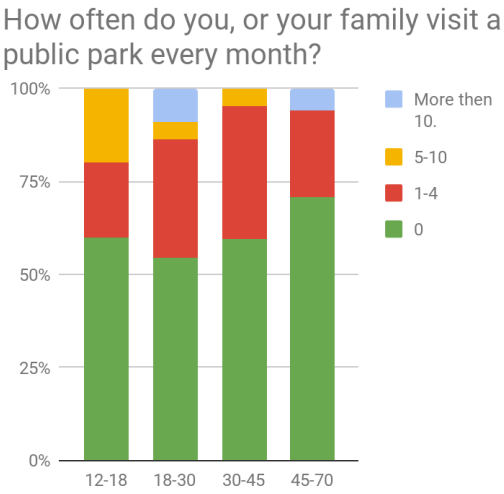


Figure 5.59 Different ages frequency of monthly park visits.

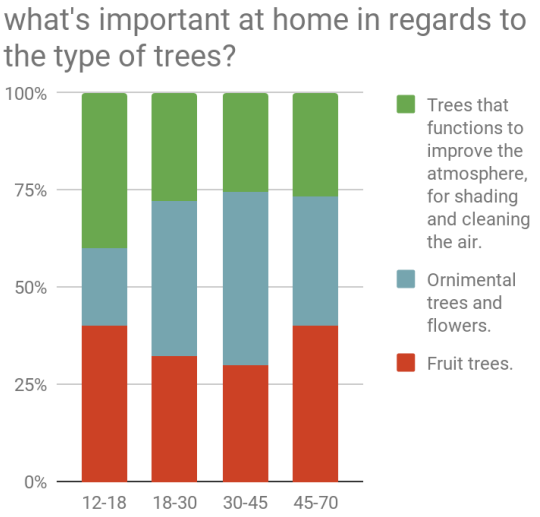


Figure 5.60 Different ages preferences in regards to the type of tree preference at home.

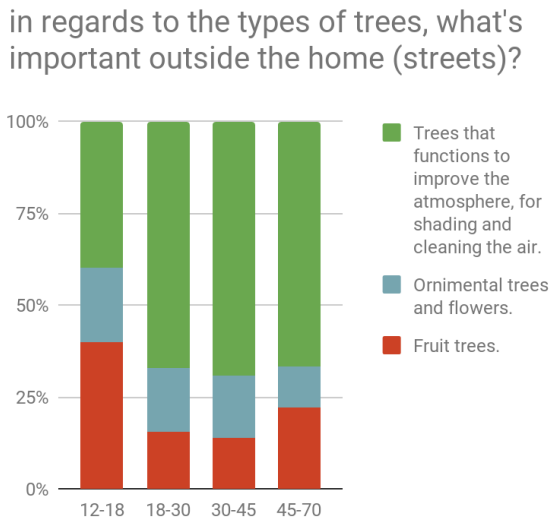


Figure 5.61 Different ages preferences in regards to the type of tree preference outside the home (streets).

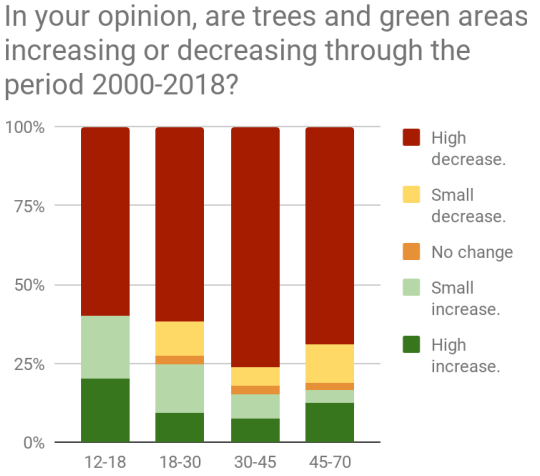


Figure 5.62 Different ages perception in regards to the the number of trees and amount of green areas change during 2000-2018.

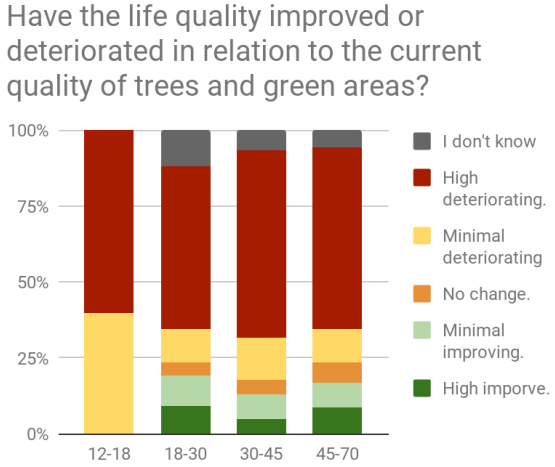


Figure 5.63 Different ages perception in regards to the life quality in regards to the current quality of trees and green areas of trees in recent years.

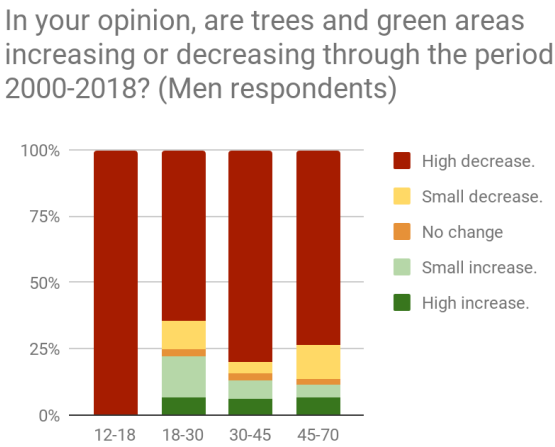


Figure 5.64 Different ages perception in regards to the number of trees and amount of green areas change during 2000-2018. (Men respondents).

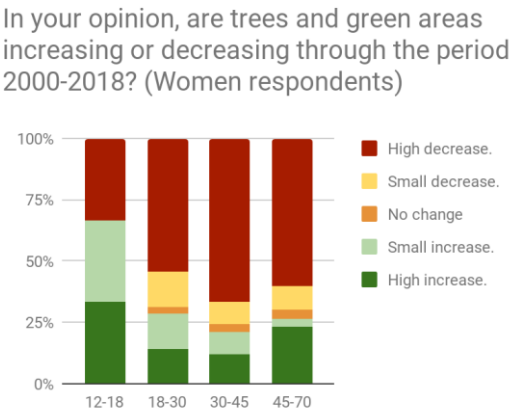


Figure 5.65 Different ages perception in regards to the number of trees and amount of green areas change during 2000-2018. (Women respondents).

CHAPTER SIX: DISCUSSION & CONCLUSIONS

6.1 DISCUSSION

Earlier in this thesis, I asked objective research question of what have been the changes of green areas in the city of Baghdad in recent history (2000-2010), which guided the method for mapping the four selected sites through the specific time period. And looking at the result, we can see that, in general, there's a clear decline in the amount green areas and number of trees, and an increase in the built up areas and sealed surfaces. Thus causing a decline. But when looking at each site, we can see a trend of different intensity depending on the neighbourhood characteristics itself. The poorer the neighbourhood is the more intense these changes have been. Spatially when looking at the case study of relatively rich neighbourhood like Al-Mansour study site, we can see that the built up area have increased a merely 8.92% and private gardens decreasing (9.69%), compared to a medium income neighbourhood like Al-Safina study site we can see that the built area have increased (14.96%) and private gardens have decreased more than (20%) going from being more than 41% to only 33% of the whole area of the study site. And when compared with a poor neighbourhood like Al-Habibiya, which had its built areas more than doubled (133% increase) with its agricultural designated land that used to comprised 51.2% in 2002 simply disappearing by the year 2010 and it's streets almost doubling in size. This extreme intensity have changed ecosystem in that part of Baghdad immensely, and the character of the area is unrecognisable when compared to its pre-2003 identity. This of course relates to the over densifying that have continued through the previous years because of the internal migration within Iraq, thus putting a lot of pressure on the housing market to spread continuously in the horizontal direction. And since in reality, the overseeing government bodies of constructions and building licence aren't doing their job properly, that's causing the illegal building on gardens and agricultural designated areas. Although historical/commercial areas (like Al-Sinak study site) did not get affected as much since they always have been extremely dense with little green areas that have shrunk.

And looking at the current existing situation in Baghdad to we can see traces of the Miastoprojekt master plan ideologies of having the green belt of agriculture going around and in some parts through the city, spatially in places like at Al-Habibiya pre-2003, and

that even though (in my opinion) the materials of choice were not very suitable for the regions climate, in general the use of private gardens as an essential part of the home, in addition to the green belt, had had a positive impact on the city of Baghdad, compared to what followed after the 2003 war.

Moreover, when looking at the number of trees, places like Al-Mansour have had the number of its trees increase by more than 21% surprisingly, and sites like Al-Safina has decreased by more than 33.9% from 2002 to 2010, in a clear correlation to each site's characteristics as expected. However what came to my surprise was in Al-Sinak there has been a increase in the number of trees from 2004 to 2010, since this part of Baghdad is highly neglected when it comes to the maintenance of green areas which comprised if a tiny (1.69%) of the whole study site in 2010.

Taking all of the mapping results into consideration, when looking at the second research objective question asked in regards to the people's perception of Baghdad, which led the development method of the questionnaire, from the survey answers, we can see that there are clear similarities between what people think and reality, when people say that "Baghdad used to be green and now it's a desert city" we can clearly say that they are right, when it comes to the amount of green areas and the number of trees. Spatially in medium and poor income neighbourhoods where the effect of urbanization has been more intense. And when it comes to the type of residency, it is clear that a lot of houses are losing their private gardens, out of the 41% of the people who currently are not living in a house with garden/forest/farm, 78% of them used to live in house with a private garden in the past, which correlates with the mapping when looking at places like Al-Safina and Al-Habibiya that have had the gardens and green areas being turned into built structures. And it ties in with their answer that the majority of respondents have said that in their neighbourhoods have lost more than half or in some cases completely all houses with gardens in recent years. On another note, the majority of people as well don't visit public parks even once a month, and one of the reasons for that is not having accessibility to a public park, since almost a 3rd of the people don't have public parks where they live, and another third lives more than a kilometre away from the closest public park.

And looking into further spatial analysis in the perception of people, differences between the men and women's responses are minimal in most cases, although men do see that the number of trees and green areas have declined more than women, and that in part could relate to the culture in Iraqi families that the men usually work during the day, and they might see and experience the differences more intensity then the women do (spatially

during the summer time), even when looking at different age groups of the two genders. The results remain similar. Moreover, when looking at the different age groups we can see more differences between young and older people, we see that people younger than 18 tend to say that "Baghdad used to be green and still is green" more than any other age group, and that is in part because they haven't in reality experienced Baghdad during a different ruling government, and they only have been aware of Baghdad that is after the 2003 war and what followed, which is why they as well say that there has been an increase in the number of trees and amount of green areas more than any other age group. Furthermore, when people were asked about the type of trees they performed at home, both women and men preferred ornamental trees the most, followed by fruit trees, and functional trees lastly. This of course comes back to the ideology of Baghdadis in general, and refers to the importance of ornamental trees and plants as a status symbol of the homeowners, in addition to fruit trees that come back to the origins of many who were farmers back in history, or have grown up with fruit trees such as citrus, olives, palm trees and others. Functional trees still is a relatively new concept that falls in between ornamental and fruit trees for Baghdadis. This can be seen in more detail when looking at the different ages in regards to the types of trees at home the majority of people prefer ornamental trees, excluding people older than 45 years, they prefer who fruit trees. However, outside the home (streets), the overwhelming majority of people older than 18 years prefer functional trees over all other types, which relates of course the way they perceive the city that it has became more desert like, and their understanding that the function of trees for shading and improving air temperature, quality, and thermal comfort can be achieved through the planting of these functional trees.

6.2 CONCLUSIONS

The hypothesis earlier in this thesis anticipated that the quality of urban environment is decreasing because of the loss of greenery on one hand, and the increase in built structures on the other, and from the results and the discussion, we can say that this statement is true in regards to the sites that were studied. Moreover, since we know from the literature review in Chapter Three that the increasing of sealed surfaces (built areas) and the decrease of green areas have a direct effect of surface and air temperatures (subchapter 3.2.1), that means that the increase in of sealed surfaces (built areas) and loss of green areas in all the study sites in Baghdad, has had a direct negative effect on the city's surface and air temperature causing higher UHI effect which in turn causes higher

heat stress during the summer (subchapter 3.3.2). In addition to, this loss in greenery means more air, soil, and water pollutants since less green areas means less vegetation to mitigate pollutants from the atmosphere (subchapter 3.3.1). And when it comes to the benefits of trees in mitigating the UHI through shading, the loss in the number of trees in areas like Al-Safina and the majority of Baghdad has a direct effect on it the temperature of the air and the surfaces that are reflecting the solar thermal energy, in addition to storing it to be remitted during the night. Moreover, when it comes to the loss of the amount of green areas loss in all the study sites, the air temperature is affected negatively since the loss in vegetative canopy means less evapotranspiration (subchapter 3.3.2). What came to my surprise was the magnitude of the reduction of green areas in some of the cases like in Al-Habibiya, where within less than 8 years went from having more than 50% of it as agriculture, into losing the agricultural designated areas all together. Nevertheless, it is possible to reach a relative thermal comfort in the outdoors throughout the year by planting of the right types of trees that provide a sufficient amount of shade (subchapter 3.4) this, in addition, will decrease the air pollution from the increased densification of the city (subchapter 3.3.2.3).

Moreover, from the second research question on what is the people's perception of the city of Baghdad, All of this loss in greenery has led to decreasing the thermal comfort for the city's inhabitants. Thus why the overwhelming majority of the questionnaire respondents say that the city has transformed from a green to a desert city, and that the living quality have deteriorated in recent years. Moreover, according to the conducted questionnaire, the people of Baghdad understand and agree that there are thermal and physiological benefits because of trees and green areas, and the majority of them are willing to participate in campaigns to plant and maintain public and private green areas. This resource should be taken advantage of by creating these events and providing small educational seminars and plants for them to work with. Although they favour a little bit more ornamental and symbolic trees and flowers at home to fruit trees and shading functional trees, they still overwhelmingly agree that outside the home in public spaces and trees it is more important to have functional shading trees that benefits and improves the air quality, in addition to the general climate conditions through reaching thermal comfort.

On another note, there is a large problem of corruption and neglect by the city officials when it comes to implementing the existing laws that prohibit the building in private gardens, agricultural lands, and urban green areas. This issue is one of the major causes for the unregulated over densifying, and it has reached a problem now of no return.

Since big neighbourhoods have appeared as a cause of this, and the government have reached a point where they simply (in my opinion) do not have the power anymore to destroy these places. However, the government can still regulate any new plans to be built in these areas by implementing the law and being very clear, and strict that there will be no more illegal building.

6.3 Final thoughts

Baghdad used to be "green" because of the strong force of authorities and the implementation of regulations. This means that the green belt that used to surround Baghdad with forests of trees and plants that helped improve the city's thermal climate situation, in addition to housing lots being not less than 200 m² which left a usual 75-100 m² of gardens in private housing and not allowing the dividing of houses into smaller houses or building in gardens which meant not allowing over densification, and since people had gardens, they were able to have trees and plants which was a usual thing in most of the houses in Baghdad, example of these trees were Citrus fruits, olive , and palm trees, all of which were encouraged by the previous regime.

6.4 RECOMMENDATIONS

6.4.1 Recommendations for the people and residents of Baghdad

- Raising awareness of the importance of *shading* and its benefits for reaching thermal comfort for architects and planners in Baghdad.
- Raising awareness of the importance and benefits of green areas for young people through school programs that are part of the curriculum.
- In the cases of people not having space to have gardens, introducing them to roof gardens that are as beneficial and have an insulating benefit for the roofs of the houses during hot summer days, in addition to having smaller plants, which still mitigate some thermal energy and air pollutants.

6.4.2 Recommendations for the municipalities and the government office of Baghdad

- Applying the laws and regulations in the cases of violations for building in gardens and agricultural designated areas.
- Having routine observations on neighbourhoods to make sure there are no violations, spatially for buildings that are being licenced to be built.

- Creating monthly campaigns for neighbourhoods to work with people to replant public areas and maintain them.
- Raising the awareness for the residents of Baghdad on the importance of green areas and shading through.
- Applying the law when it comes to the minimum amount of green areas that is required for buildings.
- Creating incentives for people with gardens to have trees by giving those plants and supporting them with information if required.
- Planting trees based on their shading functions, and tolerance towards Baghdad's climate and less on the aesthetical properties.
- The Support and incentiving of farmers and others who wish to regrow agricultural areas around Baghdad, and update or use the already existing technologies for irrigation and planting.

6.4.3 Recommendations for the government, the MCHPM and the Planning Ministry

- The right person in the right place, stopping the current system or political ruling of these department, and choosing these people based on merit and experience in the field.
- The implementation of the regulations by the responsible authorities.
- Cleansing the department of inexperienced people who are creating issues for the MCHPM and Planning Ministry and collecting salaries for doing nothing, and in some cases participating in corruption.
- A better solution for the overpopulation and the densifying of Baghdad is to rebuilding and renovating of other cities that were destroyed through the different recent wars. In addition to improving the safety and security situation.
- Decentralizing of the economical and administrative work onto other cities to relieve the pressure of densifying from Baghdad.
- Having a master plan that looks into the 10 and 30 years with clear goals and guidelines to be achieved.
-

6.4.4 Recommend species of trees for Baghdad's climate

According to a study that was done by the faculty of botanist, university of Baghdad (2012) that included most of the mentioned trees in (Appendix 5) the best option for public spaces within the city of Baghdad is to use *Albizzia Lebbek*, to be planted on the sidewalks of the main streets and highways, for it's ease and low cost of planting, speed of growth which will give short term results that could be seen, it's tolerance for heat and saltiness, it's ability to for casting a wide horizontal shadows, with an acceptable appearance, and resistance to diseases. It also doesn't need continuous watering. And since it loses its leaves during the winter it's works great for having the benefits of two seasons in one tree.

And as for the city outskirts, with recommendations from local agricultural engineers and botanists, the tree Conocarpus would work sufficiently, since it's a doesn't lose its leaves during the winter, doesn't require high maintenance, and could combat erosions and break wind from storms. It has high tolerance for diseases and cold and hot climates. It's roots go very deep and usually compact the soil below it so it can be perfect for soil erosions reduction. It already has been tested in Kuwait, Qatar, and the city of Basra south of Iraq. (Abdul-Nadeem et al., 2014). When used in cities, it requires high maintenance to have an aesthetic look, however if used for its shade and wind breaking capabilities it can function perfectly without the need of and doesn't need this high maintenance. Whilst giving a relatively aesthetical view for travellers and helping the city lower its temperature. And as for private gardens, encouraging people to plant trees other than palm trees (palm trees are liked a lot by Baghdadis for their symbolic value), like citrus, olive, and other fruit trees, since they have good tolerance for heat, and at the same time they are widely liked by people from Baghdad. In addition to smaller plants, flowers, and functional trees like Albizzia Lebbek.

6.5 Limitations and disclaimers

Some of the limitations and issues facing the study:

- were the availability of data in regards to the history of Baghdad that is not politically biased
- The difficulty of finding official data from the government websites that are mostly functioning as a public announcement platform with extremely confusing user interface, and in the cases where some data reports were found, they looked extremely unreliable, and not scientific, as if it wasn't done by an experts.

Moreover, when using trying to contact these government bodies through the official outlets (email addresses and phone numbers) there was never a response.

- When managed to contact some government officials through unofficial channels, the majority refused to speak about their departments for fears of retaliation by superiors, fear of being fired, or in some cases security fears. This of course prohibits the development of the MCHPM and Planning Ministry since in many cases, wrongdoing is not being reported.
- The lack of availability of more frequent and recent satellite images of Baghdad might have given a more accurate image of the developments in the study.
- The translation of the questionnaire data, which has caused some problems with the ability to conduct a more comprehensive detailed analysis.
- The size of the questionnaire sample (323) might have been bigger if it had more time to spread, and through more effort of publishing it through more outlets.

Disclaimer: The mapping results are for the specified period of time and are not 100% accurate since the mapping was done using satellite images, and not on the ground measuring. Moreover, this mapping is not representative of the current situation in Baghdad (which I anticipate is worse than the study findings) since the latest available satellite images of Baghdad were from 2010.

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APPENDICES

Appendix 1 Detailed description of the mapping method

A1.1 Getting the Satellite Images with the Correct Georeferencing.

The software *Google Earth pro v7.3.2* was used to gather the raster images, along with another software called *Smart GIS v2018* in order to get the images with the correct geographical coordinates on them. After downloading both programs and setting up *Google Earth pro* options from the tools menu according to the settings specified by the *Smart GIS v2018* manual. I started the program *Smart GIS v2018* and from the tools menu I chose the 'Download from Google Earth ….' which prompted a small window, then by pressing on 'Login Google' the software started the application *Google Earth pro* and a green sentence below saying 'Google Earth is Connected' appeared. At this point, I was able to input the coordinates (Longitude in degrees, Latitude in degrees, and height which is specified in meters) of the areas I needed to take images of while saving those images with the correct coordinates using the 'Import Rectified Image' button. And using the (Up, Down, Left, Right) buttons, it was possible to take multiple images with the right coordinates of areas to have a higher resolution for mapping while maintaining the correct height and distance between images. And at the same time, saving these images in Google Earth again in a coloured format since the program *Smart GIS v2018* only saves images in black and white. And I also used the tool 'Historical Imagery' which can be found in the 'view' menu. All of these images were organised according to the following structure:

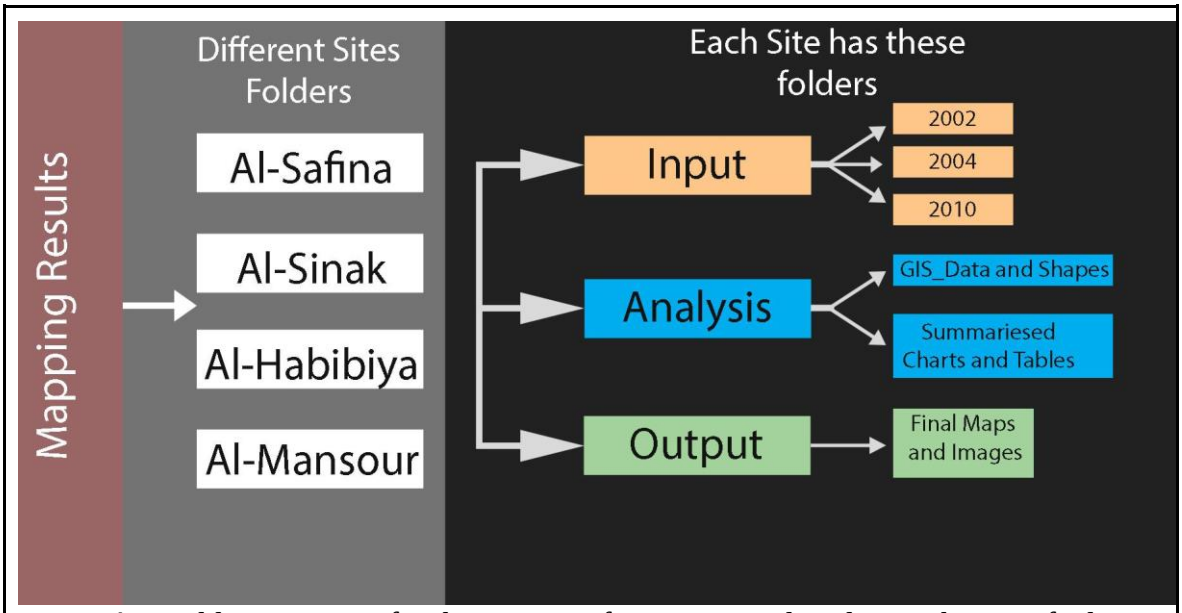

Figure A1 Folders structure for the process of mapping and analysing the specified sites for the specified time period.

A1.2 Importing the satellite raster images into the GIS software and setting them up for further analysis.

After the creation of a file with the name of the specific neighbourhood with the *ArcMap v10.6.1* software which deals with GIS (Geographical Information System) modelling and data. The map document was set to 'store the date relative pathnames to the data source' from the 'Map Document Properties' in the 'File' menu in order to make sure there will not be any issues with the files importing and to create a pipeline of work that works for the other sites. The images were imported into the in order to accurately calculate the changes that have happened throughout the time reference points in the chosen areas of the city of Baghdad. The raster images were also grouped by year, and their contrast for the raster images of (2002 & 2004) have been adjusted for -30% in order to have a clearer image to work with. All the images were grouped later on to one group called 'BaseMaps' for ease of control for the rest of the project. The geographical coordinate system for the data frame was set to '*WGS_84'* (World Geodetic System 1984) datum for the imported images with the coordinates through the (Layer / Properties / Coordinate System).

A1.3 Creating vector file 'polyline' to separate and identify the specific different landscape categories

The images of 2004 and 2010 were switched off, and only the images on 2002 were turned on in order to make the analytical date for 2002. After that a 'Shape file' was created through the Catalogue window and within the folder (dir/Analysis / GIS_DATA and Shapes/), with a (right click of the mouse/New/Shapefile…) this prompted a window, which I chose in the name of this shape file "Outlines_2002", and the feature type as 'Polyline', and the coordinate system as '*WGS_84'*. After creating this file, I enabled the editing of this file through the (Edit Feature/Start Editing) and with the mouse I choose the 'Outlines_2002' in the 'Create Features' window, and chose 'Polyline' in the 'Construction Tools' tab of the mentioned window. Then created polylines around the study area, and created enclosed polygons within the study area of the specified site to represent different landscape categories including (Buildings, Empty Lots, Streets, Green Areas, Agricultural area, Private Gardens, Open Areas) depending on the site and the time reference.

A1.4 Transforming the polylines into polygons

Then these polylines were transformed into Polygons using the 'Feature to Polygon' tool that can be found in (Geoprocessing/Data Management Tools/Features/Feature To Polygon) and choosing the input feature as 'Outlines_2002' and the output Feature Class as "Zones_Categories_2002w" and to be saved in (dir/Analysis / GIS_DATA and Shapes/). After the creation of the polygon,

A1.5 Transforming the polygons geographical projection coordinate system into a projected coordinate system

The geographical projection was transformed into the projected coordinate system '*WGS_1984_UTM_Zone_44N'* (World Geodetic System 1984 zone 44 north, since Baghdad is on the 44th parallel Latitude) using the tool (Geoprocessing/Data Management Tools/Projections and Transformations/Project). And choosing the Input Dataset or Feature Class as 'Zones_Categories_2002w' and the output Data set or Feature Class as "Zones_Categories_2002c" and the Output Coordinate System as '*WGS_1984_UTM_Zone_44N'* and checking the 'Preserve Shape (Optional)' box to be sure that the shapes were not distorted.

A1.6 Adding different attributes fields, and calculating the areas of different land categories.

The Attributes Tables was opened for the new file ‘Zones_Categories_2002c’, and the following fields were added with (Table Options/Add field): “LU_CAT” for the different Landscape Categories with type as ‘Text’ and the Length as 30, and “Area”, to represent the area of each polygon with type as ‘Double’ and Precision as 0 and scale as 0.

The area of each polygon was calculated in square meters with the use of the ‘Calculate Geometry’ tool that can be reached by (right click of the mouse on the specified field/Calculate Geometry) and choosing Area for the ‘Property’ and the ‘Use coordinate system of the data source: PCS: WGS 1984 UTM Zone 44N’ and the Units as Square Meters [sq. m].

A1.7 Modifying the appearance of the new layer and adding the different values “names” to the landscape categories shapefile.

By going to the Layer properties of ‘Zones_Categories_2002c’ the transparency was changed to 50 [%] in ‘transparent:’ in the ‘Display’ tab. And the Symbology was changed from the default ‘Features’ into ‘Categories/Unique Values’ and the ‘Value Field was set to ‘LU_CAT’. Then using the ‘Add Values button, the following Values were added “Buildings, Empty Lots, Streets, Green Areas, Agricultural area, Private Gardens, Open Areas” in the prompted window by writing the name and pressing the ‘Add to List’ button, the values were added depending on the site and the availability of the mentioned values in it. And then the following colours were set in the symbol selector by pressing on the colour box of each one of the new Values and the colours were saved with these names to make it easy to unify the colours across the other sites and time references: Streets ‘Arctic White’, Green Areas/Gardens ‘Leaf Green’, Empty Lots ‘Delft Blue’, Buildings ‘Seville Orange’, Open Areas ‘Heliotrope’, Agriculture ‘Tzavorite Green’.

A1.8 Assigning the specified land categories to the polygons.

After putting the new ‘Zones_Categories_2002c’ polygon file in the editing mode, and using the mouse cursor to select similar categories (eg, Buildings) and then changing their attributes into ‘Buildings’ in the Attributes tab, repeating that for the other attributes as well.

A1.9 Summarising the area for all the different land categories.

After having all the polygons with the right attribute category, and saving the edits in (Editor/Save Edits) and stopping the edit in (Editor/Stop Editing). and since the area was already calculated, now it's possible to summarize the found data using the summarize tool on the LU_CAT field in the Attributes Table, that can be found by (right click of the mouse on the LU_CAT field/Summarize) in the Select a field to summarize: 'LU_CAT' and in the Choose one or more summary statistics to be included in the output table: 'Area/Sum' and choosing the location as (dir/Analysis / Summarized Charts and Tables) and the name of the file "Summarized_2002". Which calculated the sum of the different landscape categories areas. This information was later inputted into Google Sheets for further analysis of the differences and changes that occurred throughout the specified time period of each site of the study cases.

A1.10 Creating feature to calculate the amount of trees on the specified site and time

Another 'Shapefile' was created through the Catalogue window and within the folder (dir/Analysis / GIS_DATA and Shapes/), with a (right click of the mouse/New/Shapefile…) this prompted a window, which I chose in the name of this shape file "Trees_2002", and the feature type as 'Point', and the coordinate system as 'WGS_84'. After creating this file, I enabled the editing of this file through the (Edit Feature/Start Editing) and with the mouse, I choose the 'Trees_2002' in the 'Create Features' window, and chose 'Point' in the 'Construction Tools' tab of the mentioned window. Then created points as a representation of every tree within the specified study zone in the image of the specified year.

In the 'Layer Properties' of the shapefile 'Trees_2002' the Feature 'Single Symbol' was chosen in the 'Symbology' tab, and a symbol, the 'Circle 2' was chosen with the colour 'Green', and Size '10.00' and Angle '0.00'.

A1.11 Map Settings and exporting

At this point, the following information were available; the images of the site with the correct coordinate system, correctly projected in the *ArcMap* software, along with the different landscape categories projected as a polygon above the mentioned images, with symbolic colours to represent different types and categories of land cover, with trees shapefile that has a point representing each tree in the site.

The file's 'Page and Print Setup' was opened from the 'File' menu, and the Printer Setup was chosen as 'Microsoft Print to PDF', and in the Paper section of the prompted window, the Size was set to 'A4', the Orientation was set to 'Landscape' and in the Page section of the prompted window, the Standard Sizes was set to 'A4', with the Width to 297 millimetres, and Height to 210 millimetres and the Orientation as Landscape.

The view was changed to the 'Layout View' in the 'View' menu, and from the 'insert; menu, a 'Title' was inserted and filled with the name of the site , a subtitle as 'text' containing information about the year of the map, along with other texts as metadata of the prepared map, a 'Legend', a 'North Arrow', a 'Scale Bar', a 'Picture' for the Pie chart that was created in google sheets, another 'Picture' for the location map of Baghdad. The scale was set depending on the site. And after arranging everything together, the map was exported from the 'Export Map' tool in the 'File' menu, with '96' dpi, in the Folder (dir/Output /Final Maps and Images) with the name "NameOfSite_Year" as a *.png to be used later for further analysis.

This process was repeated with the images of 2004, and 2010 and for all the mentioned study sites.

A1.12 Further analysis of the mapping results data and the generating of charts.

All the calculated data from the mapping was inputted into a Google Sheets file called "Mapping Results", with 4 Sheets created to represent each site separately, each sheet file included the detailed land categories for each year, and a sum of said categories into three (or two in some cases) types of areas "Green Areas" which included Gardens, Empty Lots that are green, Open Areas that are green and Agricultural areas, and "Built Areas" which included Buildings, Streets, Empty Lots that are not green, Open Areas that are not green.

These detailed information were used to calculate the percentage of green areas for each specified year by using the formula "Green Areas/Built Areas", and see the increase or the decrease of different categories by the same technique.

This information was finally turned into bar charts 'Column Chart' to make it visually easier to understand and see the difference and changes that have occurred for the main categories, and for the detailed categories. And a bar chart was created with the type '100% stacked Column chart' with the detailed land categories throughout the specified time period. The charts were given appropriate titles to make it easy to find and organise in the future.

A1.13 exporting of charts and tables from google sheets.

The charts that were created in the file 'Mapping Results' were imported into the thesis file using the built in tools within google doc, through (Insert-Chart, From Sheets..) after that, choosing the desired charts to import from the google sheet file 'Mapping Results'. These charts are interactive, meaning that if the data was to be updated, the charts would update as well.

Appendix 2 Questionnaires questions.

The questions that were used to gather information about the people's perception of Baghdad, and the green structures.

1. General info (Age, Sex, education level, resident of Baghdad or not).
2. The image (the way it's seen) of Baghdad?
3. How often do people visit public parks?
    a. How far do people live from public parks? (Approximation)
    b. Can you access these public parks free?
    c. How far do you live from the closest public park? (Approximation).
4. Type of residence
    a. Type of current residence?
    b. Type of past residence?(in the case that the current residence doesn't have access to a garden).
5. in the neighbourhood of the person filling the survey
    a. Percentage of homes with private gardens? (Approximation)
    b. Percentage of houses that used to have private gardens but have been built recently? (Approximation)
6. Thermal and psychological comfort in the opinion of the person filling the survey:
    a. If there's a relation between trees and thermal comfort in the home? (opinion)
    b. If there's a relation between trees and thermal comfort outside of the home? (opinion)
    c. If there's a relation between trees and psychological comfort in the home? (opinion)
    d. If there's a relation between trees and psychological comfort outside of the home?(opinion)

7. Amount of trees, plants, and green areas in the opinion of Baghdad's residents and visitors from 2000-2018:
    a. Do you see the trees increasing or decreasing? (opinion)
    b. Living quality is improving or deteriorating? (opinion)
    c. What's important for the people at home? In relation to the type of trees (type of tree: ornamental and beauty value - fruit tree value - functional for heat, shading, and soil and wind breaking value). (opinion)
    d. What's important for the people outside the home (streets)? In relation to the type of trees (Type of tree: ornamental and beauty value - fruit tree value - functional for heat, shading, and soil and wind breaking value). (opinion)
8. Willingness to participate in campaigns to replant trees and help maintain green areas?

    Depending on the answer of previous question
    a. How often are people willing to participate?
    b. The body that should organise these campaigns?
9. Amount of Sand storms in the opinion of Baghdad's residents and visitors from 2000-2018
    a. Are storms increasing or decreasing from 2000-2018? (opinion)
    b. Is there a direct connection between the amount of trees and sand storms? (opinion)
    c. Living quality is improving or deteriorating in relation to the sand storms? (opinion)
10. Future Communication
    a. Contact email address.
    b. Willingness to participate in future surveys and campaigns in relation to this survey and research topic.

Appendix 3 Mapping results maps

A3.1 Site 1 Al-Mansour

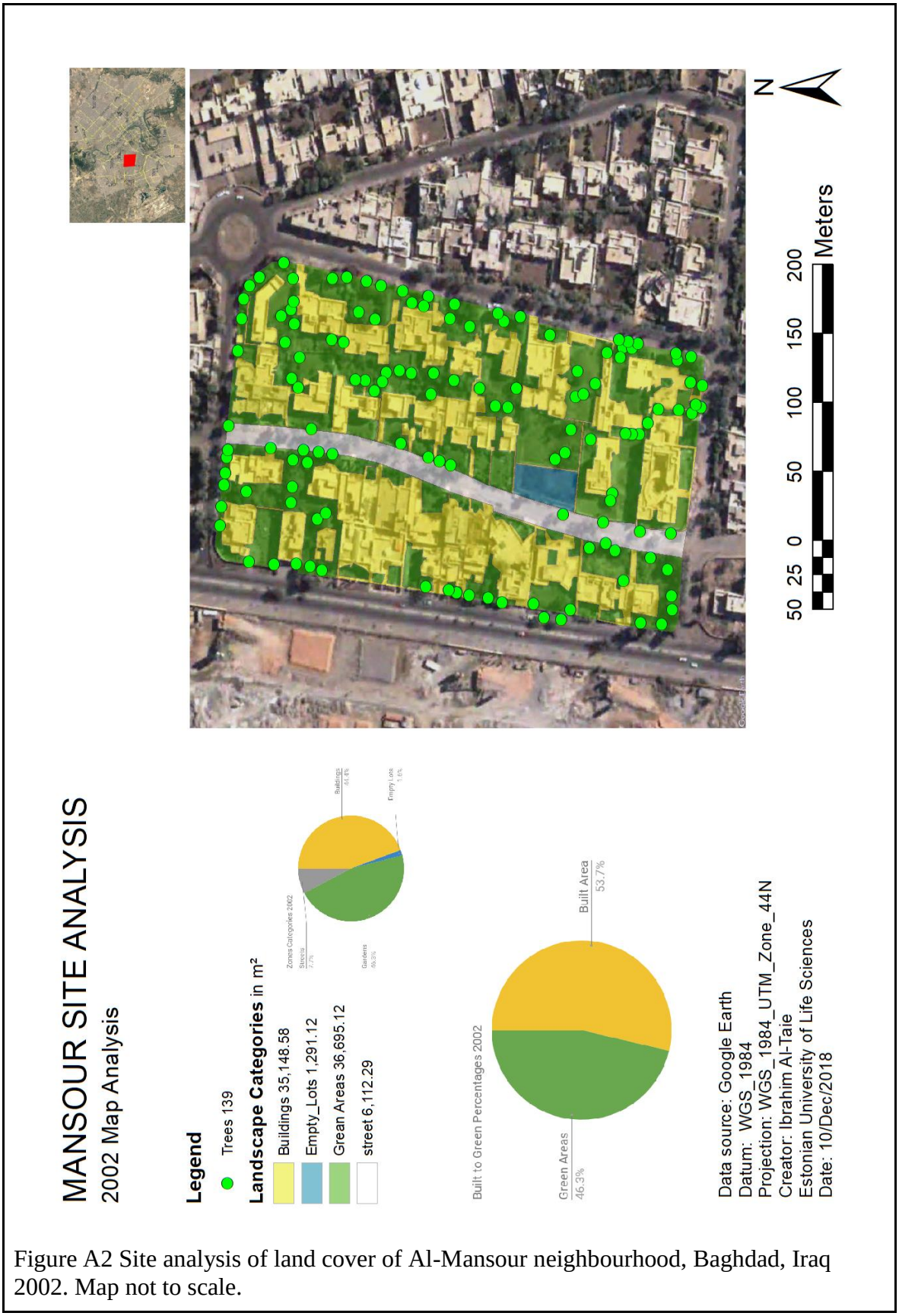

Figure A2 Site analysis of land cover of Al-Mansour neighbourhood, Baghdad, Iraq 2002. Map not to scale.

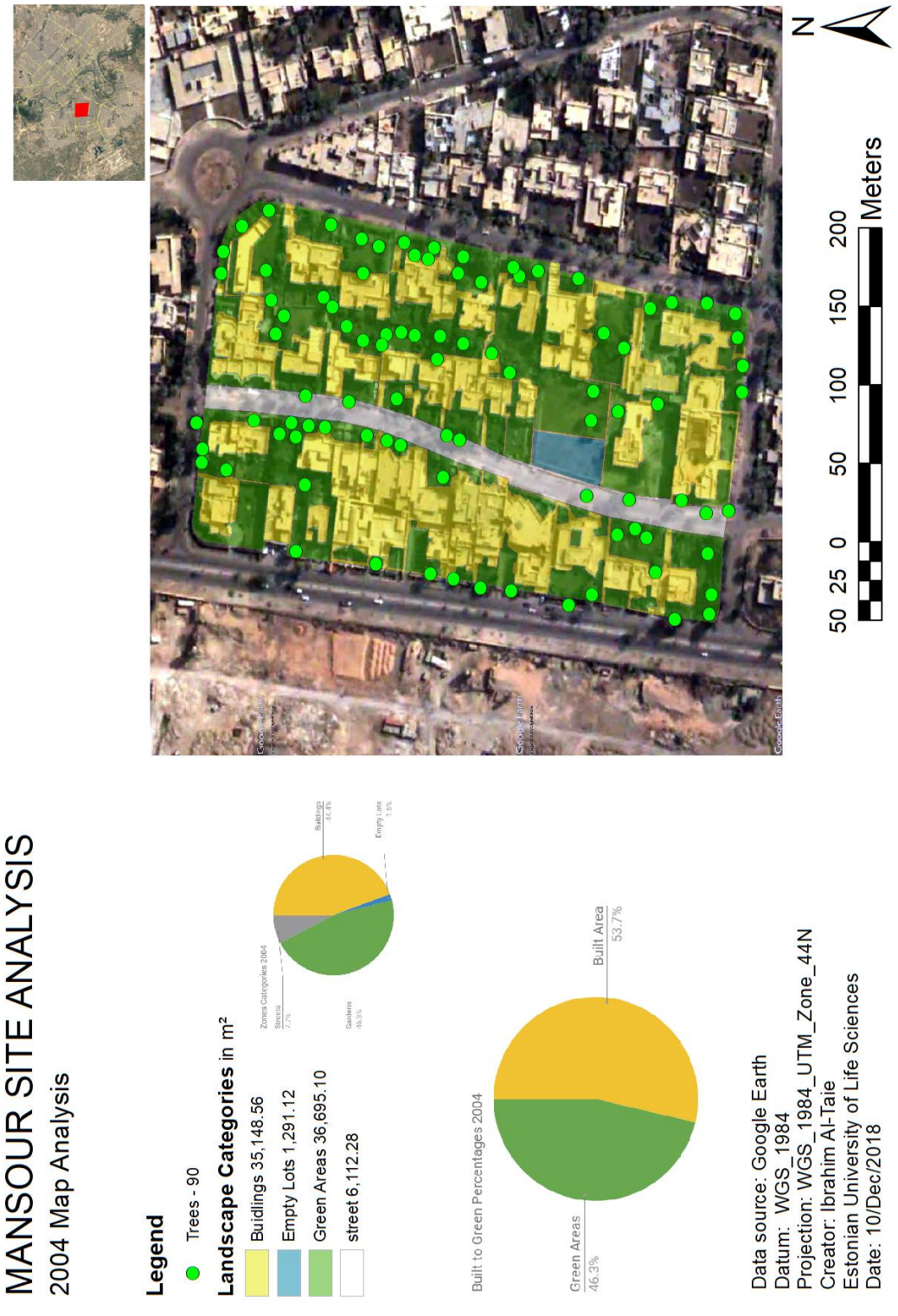

Figure A3 Site analysis of land cover of Al-Mansour neighbourhood, Baghdad, Iraq 2004. Map not to scale.

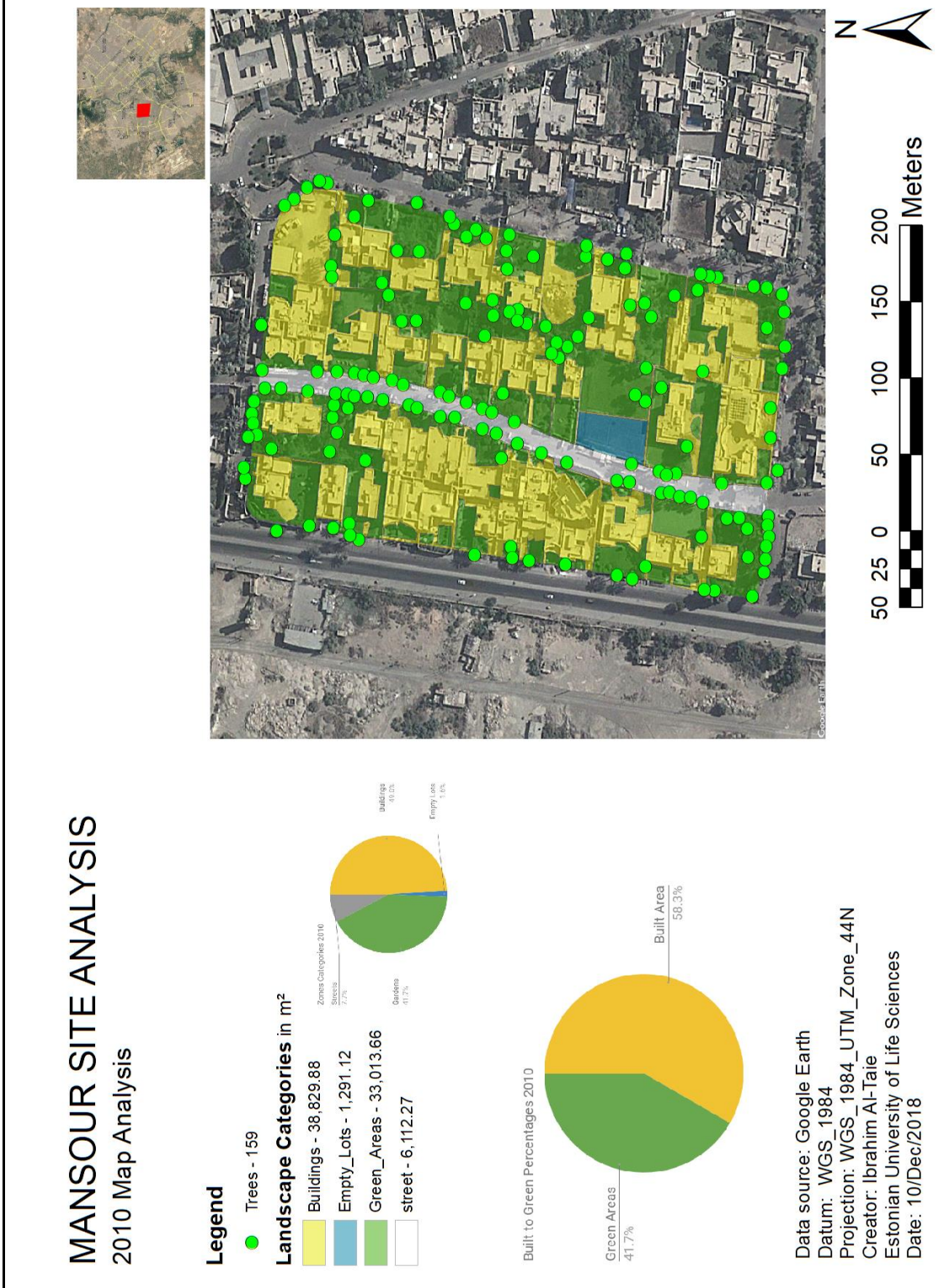

Figure A4 Site analysis of land cover of Al-Mansour neighbourhood, Baghdad, Iraq 2010. Map not to scale.

A3.2 Site 2 Al-Safina

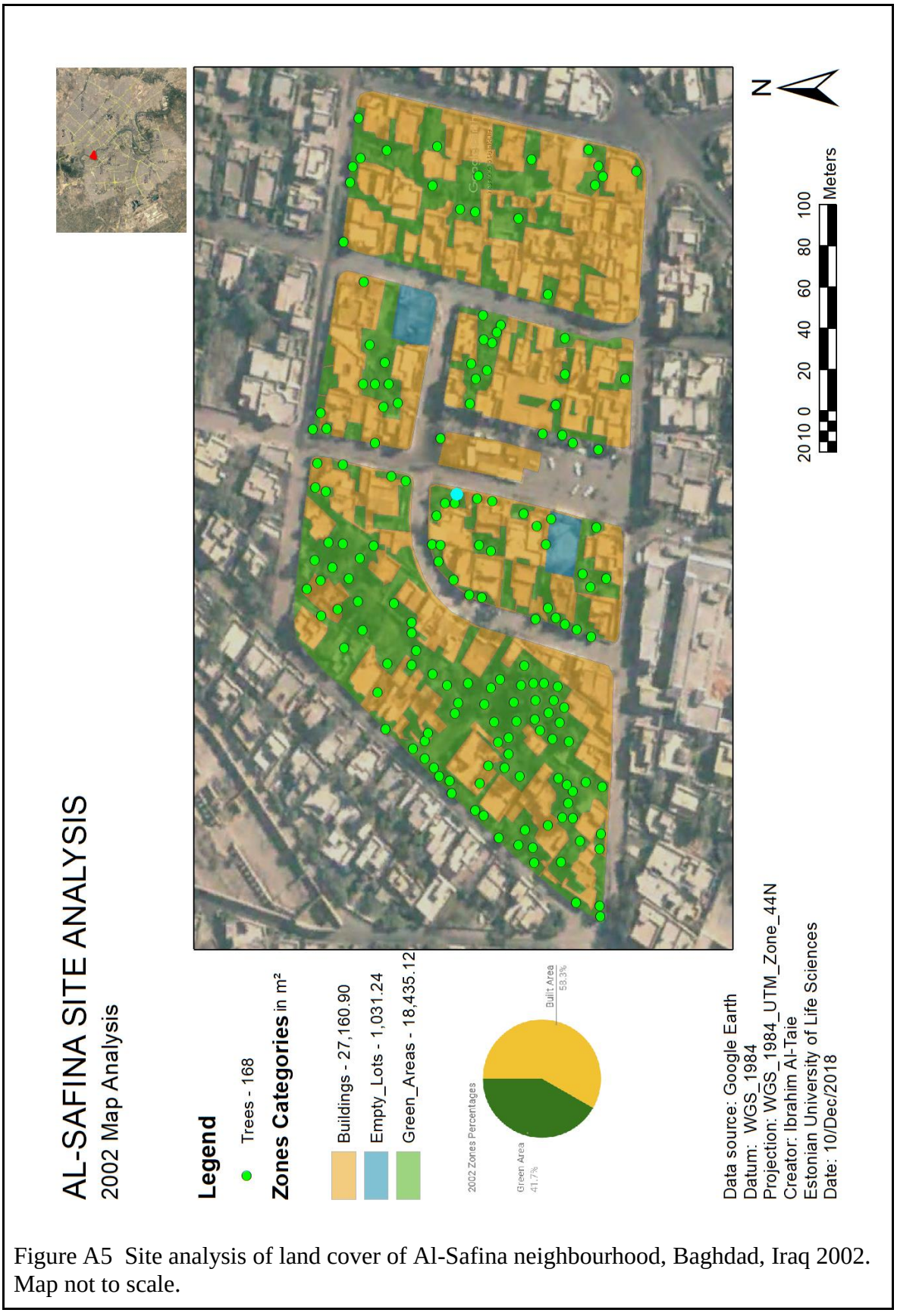

Figure A5 Site analysis of land cover of Al-Safina neighbourhood, Baghdad, Iraq 2002. Map not to scale.

Figure A6 Site analysis of land cover of Al-Safina neighbourhood, Baghdad, Iraq 2004. Map not to scale.

Figure A7 Site analysis of land cover of Al-Safina neighbourhood, Baghdad, Iraq 2010. Map not to scale.

A3.3 Site 3 Al-Habibiya

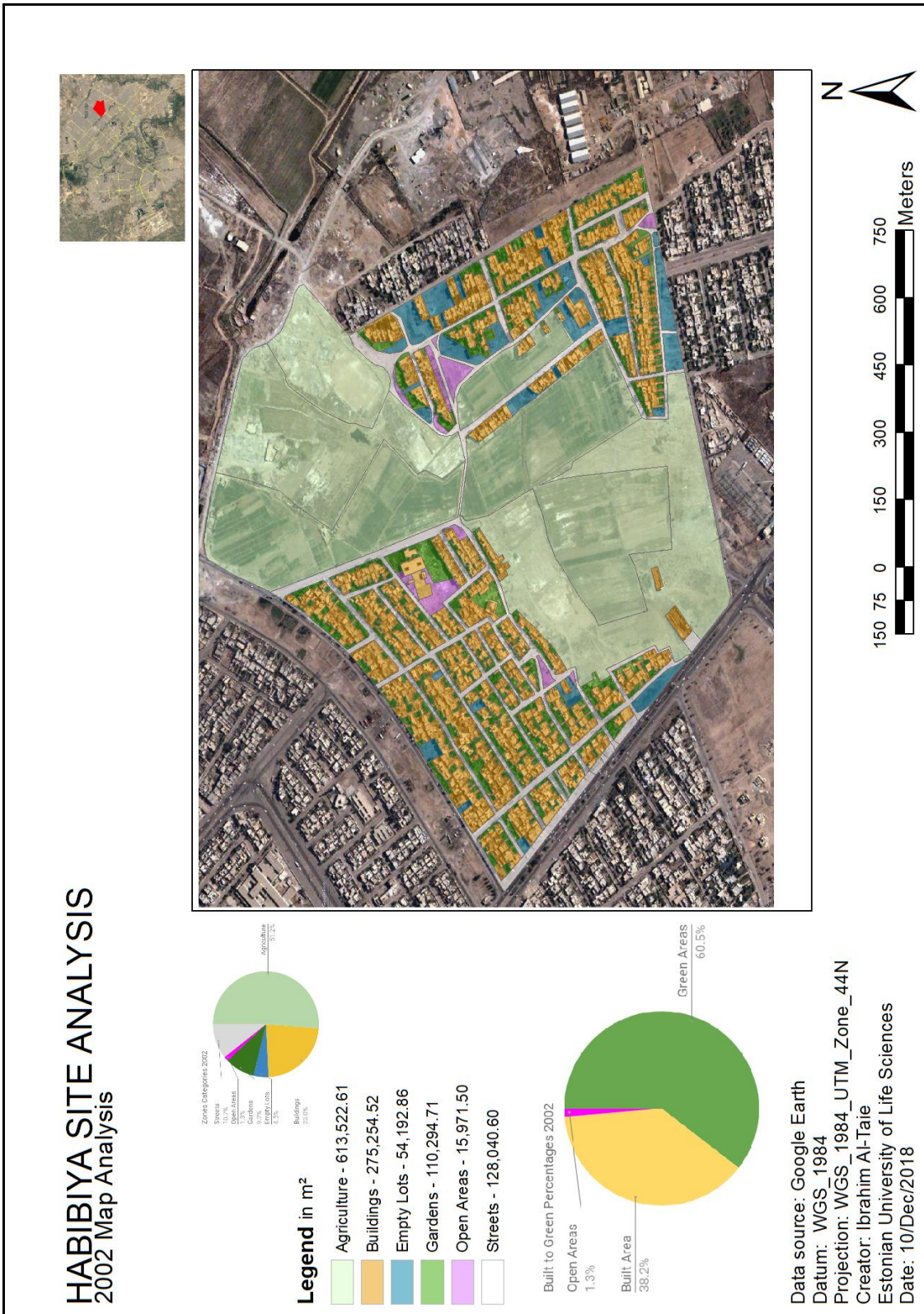

Figure A8 Site analysis of land cover of Al-Habibiya neighbourhood, Baghdad, Iraq 2002. Map not to scale.

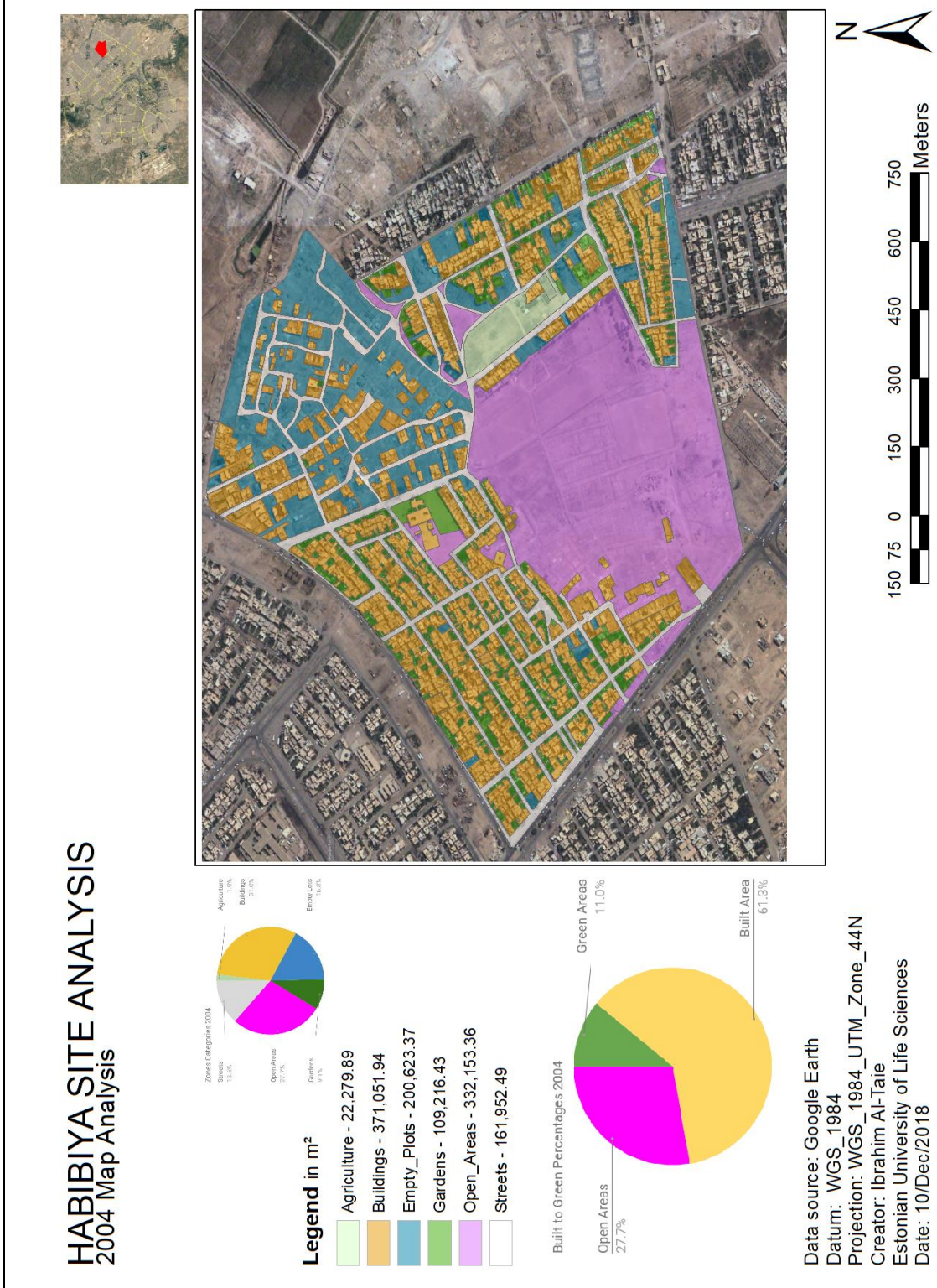

Figure A9 Site analysis of land cover of Al-Habibiya neighbourhood, Baghdad, Iraq 2004. Map not to scale.

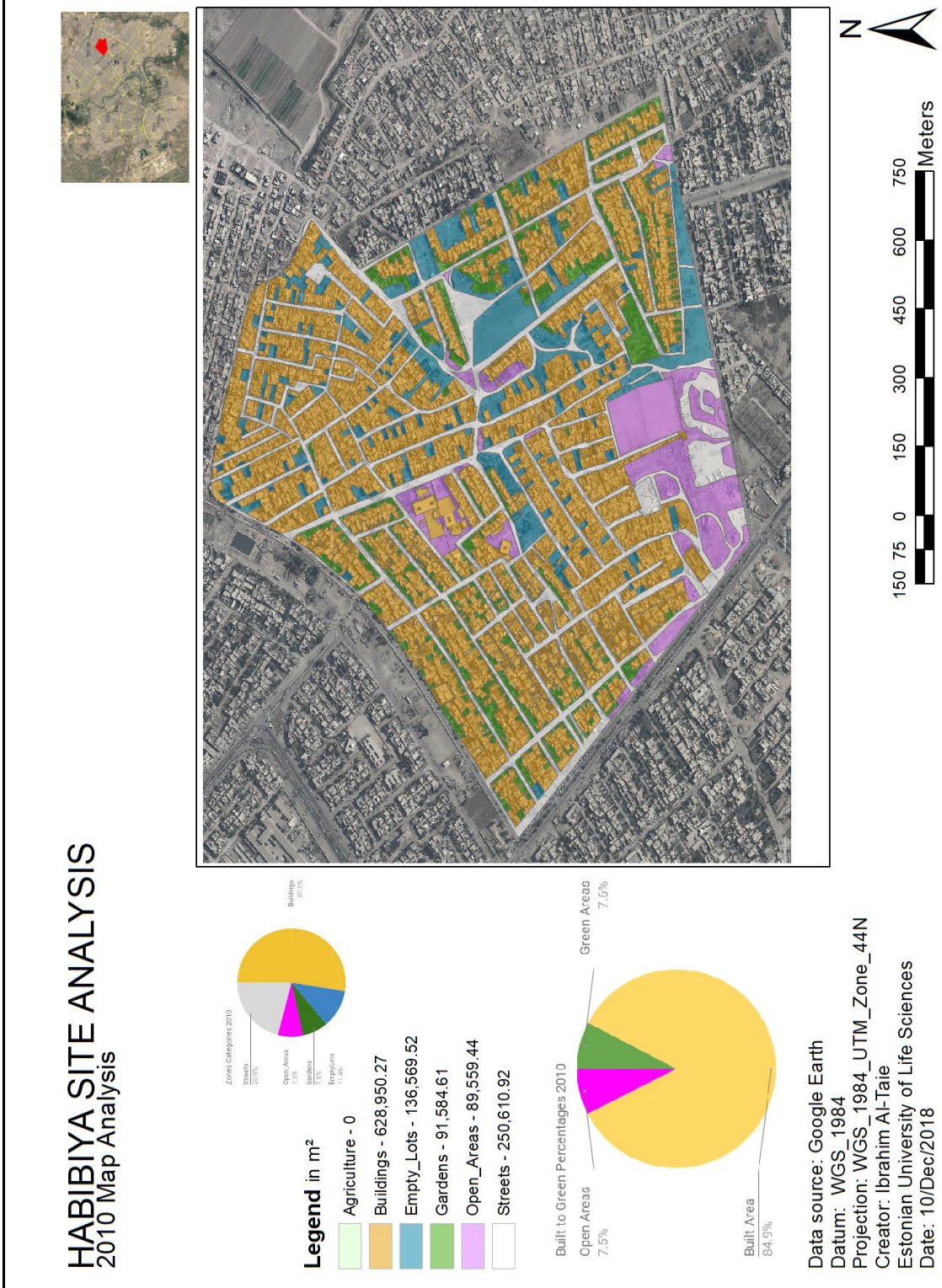

Figure A10 Site analysis of land cover of Al-Habibiya neighbourhood, Baghdad, Iraq 2010. Map not to scale.

A3.4 Site 4 Al-Sinak

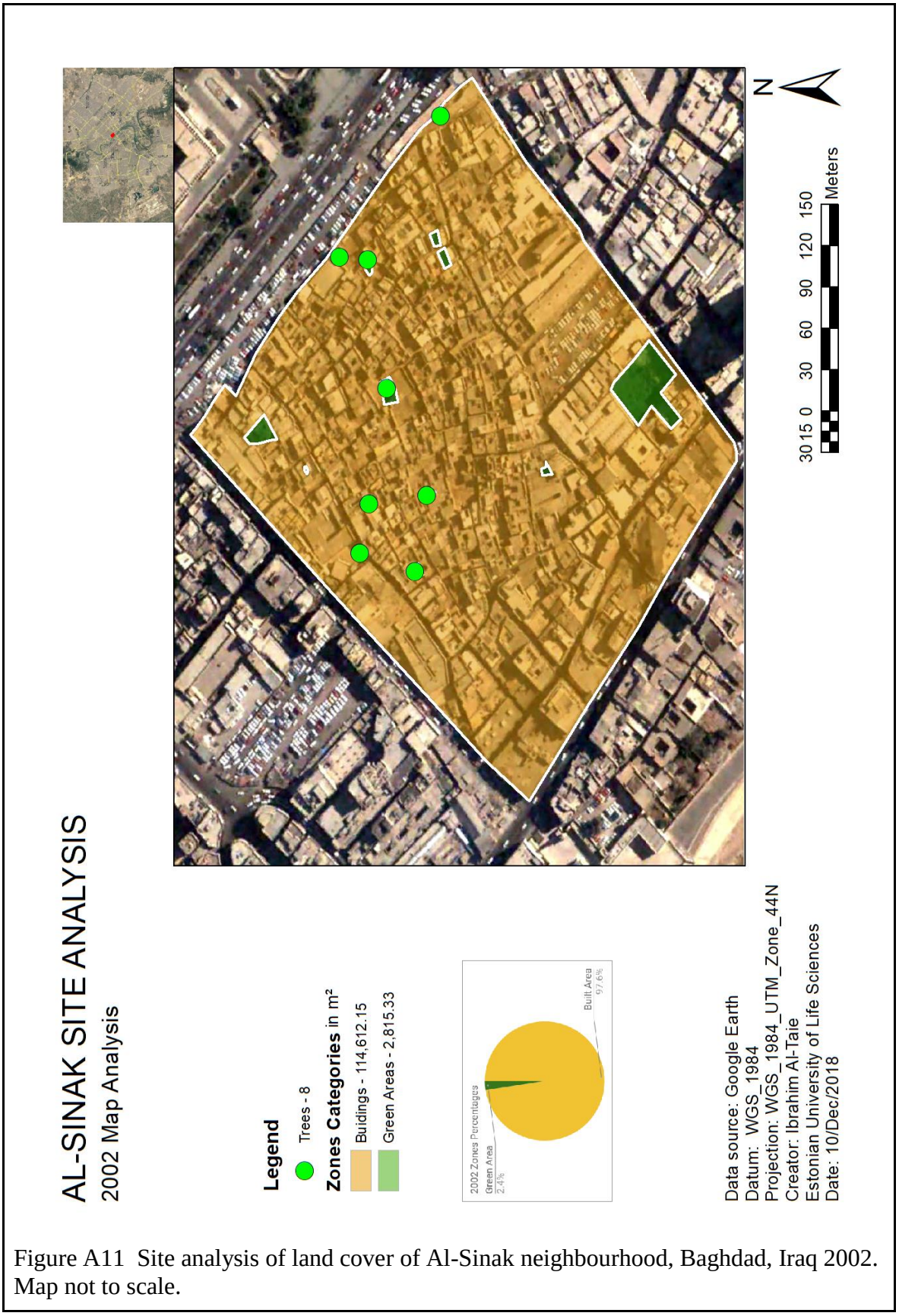

Figure A11 Site analysis of land cover of Al-Sinak neighbourhood, Baghdad, Iraq 2002. Map not to scale.

Figure A12 Site analysis of land cover of Al-Sinak neighbourhood, Baghdad, Iraq 2004. Map not to scale.

Figure A13 Site analysis of land cover of Al-Sinak neighbourhood, Baghdad, Iraq 2010. Map not to scale.

Appendix 4 Mapping Results tables

Years	Land Categories in m²				No. of Trees
	Built Area	Green Area	Empty Lots	Streets	
2002	35,148.58	1,291.12	36,695.12	6,112.29	131
2004	35,148.56	1,291.12	36,695.10	6,112.28	90
2010	38,829.88	1,291.12	33,013.66	6,112.27	159
change in percentage	10.47%	0.00%	-10.03%	0.00%	21.37%

Table 3 Mapping results of Al-Mansour study site.

Years	Land Categories in m²			No. of Trees
	Built Area	Green Area	Empty Lots	
2002	27,160.90	18,435.12	1,031.25	168
2004	28,656.32	17,970.93	0.00	117
2010	31,225.53	15,401.66	0.00	111
change in percentage	14.96%	-16.45%	-100.00%	-33.93%

Table 4 Mapping results of Al-Safina study site.

Years	Land Categories in m²					
	Buildings	Gardens/Gardens	Empty Lots	Streets	Agriculture	Open Areas
2002	275,254.52	110,294.71	54,192.86	128,040.60	613,522.61	15,971.50
2004	371,051.94	109,216.43	200,623.37	161,952.49	22,279.89	332,153.36
2010	628,950.27	91,584.61	136,569.52	250,610.92	0.00	89,559.44
change in percentage	128.50%	-16.96%	152.01%	95.73%	-100.00%	460.75%

Table 5 Mapping results of Al-Habibiya study site.

Years	Land Categories in m²		No. of Trees
	Built Area	Green Area	
2002	114,612.15	2,815.34	8
2004	114,866.74	2,561.03	5
2010	115,437.28	1,989.98	9
change in percentage	0.72%	-29.32%	12.50%

Table 6 Mapping results of Al-Sinak study site.

Appendix 5 Suitable species

In order to get relative data to Baghdad, the following analysed and examined different types of trees that are suitable and proved survivability and high tolerance to the region's conditions, the following are the species were recommended and mentioned by botanists and agricultural engineers from Iraq through interviews that were conducted online:, the first one being *Date Palm (Phoenix dactylifera)* : one of the most indigenous trees to the region since the times of Mesopotamia, it was recently planted all around Baghdad as well by the Baghdad municipality as a shading tree for the main roads and highways. It has a symbolic importance for Iraqis historically, and it is a typical tree in Iraqi homes. The second one being *Eucalypts*: one of the trees that have been adapted to the country's climate conditions. The third one is *Gleditsia species*: an environmental and economical invasive weed/tree that grows very fast with a high reproduction capacity. Although it has a short life span of 120 years, it needs minimal maintenance and has a high tolerance towards hot climate. Fourth one being *Albizia lebbeck*: which was recommended the most frequently for public spaces. In addition to *Jacaranda Mimosifolia, Bombax Malabaricum.* Lastly, *Conocarpus*, which was recommended for the outskirt of the city for its high tolerance for climate conditions, speed of growth and low maintenance requirements for the function of having a green belt around the city. Below (Table 7) shows images of the mentioned trees.

Table 7 Recommended trees images.

A14 Phoenix dactylifera. (Wikimedia)a

Figure A15 Eucalypts. (Wikimedia)b

Figure A16 Gleditsia species. (Wikimedia)c

Figure A17 Albizia lebbeck (asergeev.com)

Figure A18 Jacaranda Mimosifolia (California Polytechnic State University website).

Figure A19 Bombax Malabaricum (The ferns).

Figure A20 Conocarpus (Greensouq).

The mentioned species above were analysed with the following with evaluation parameters (Table 8) to have a more clear and statistical answer to choose from.

Table 8 Evaluation of elected trees for public spaces. (Al-Jawadi et al., 2014).							
Scientific name	Phoenix dactylifera	Eucalypts	Gleditsia species	Albizia lebbeck	Jacaranda Mimosifolia	Bombax Malabaricum	Conocarpus
Density of leafs	Low	Medium	High				
Shape of the tree	Top disc	Irregular	Spherical	Oval (horizontally)	Oval (vertically)		
General look of the tree/plant	Thin trunk, end buds	Vertical forked trunk and bulks of leafs	Vertical trunk and bulks of leafs				dense multiple-trunked shrubs or small to medium-sized trees
Plant height in meters	12-15+	12-30	0.8-12	8-12	12-15	12-18	1-20
Diameter in meters	0.5	0.8	0.8	0.9	1	1	0.4
Area covered by tree in m^2	20	70	70	70	125	150	8
Duration of growth	Medium	Fast	Fast	Fast	Medium	Medium	Fast
Type of leafs	Bulky feathery leafs	Spherical leafs	Bulky feathery leafs	Bulky leafs	Bulky feathery leafs	Bulky feathery leafs	Bulky leafs
Leafs mass	Permanent	Permanent	Seasonal	Seasonal	Seasonal	Seasonal	Permanent
Tolerance towards diseases	High	Medium	Medium	High	Medium	Medium	High
Tolerance towards climate	High	High	High	High	Doesn't tolerate the cold	Doesn't tolerate saltines	High

						s	
Maintenance need	High	Low	Low	Low	High	Mediu m	Medium
Reproductio n capacity	High	High	Low	High	Low	Low	High
Aesthetic features	High	Mediu m	Medium	High	Medium	High	High
Shading efficiency of horizontal surfaces	Low	Mediu m-high	Medium -high	Medium -high	High	High	High
Wind breaker	Low	Mediu m	Medium	High	Medium	High	High
Fruit tree	Seasona lly	No	No	No	No	No	no